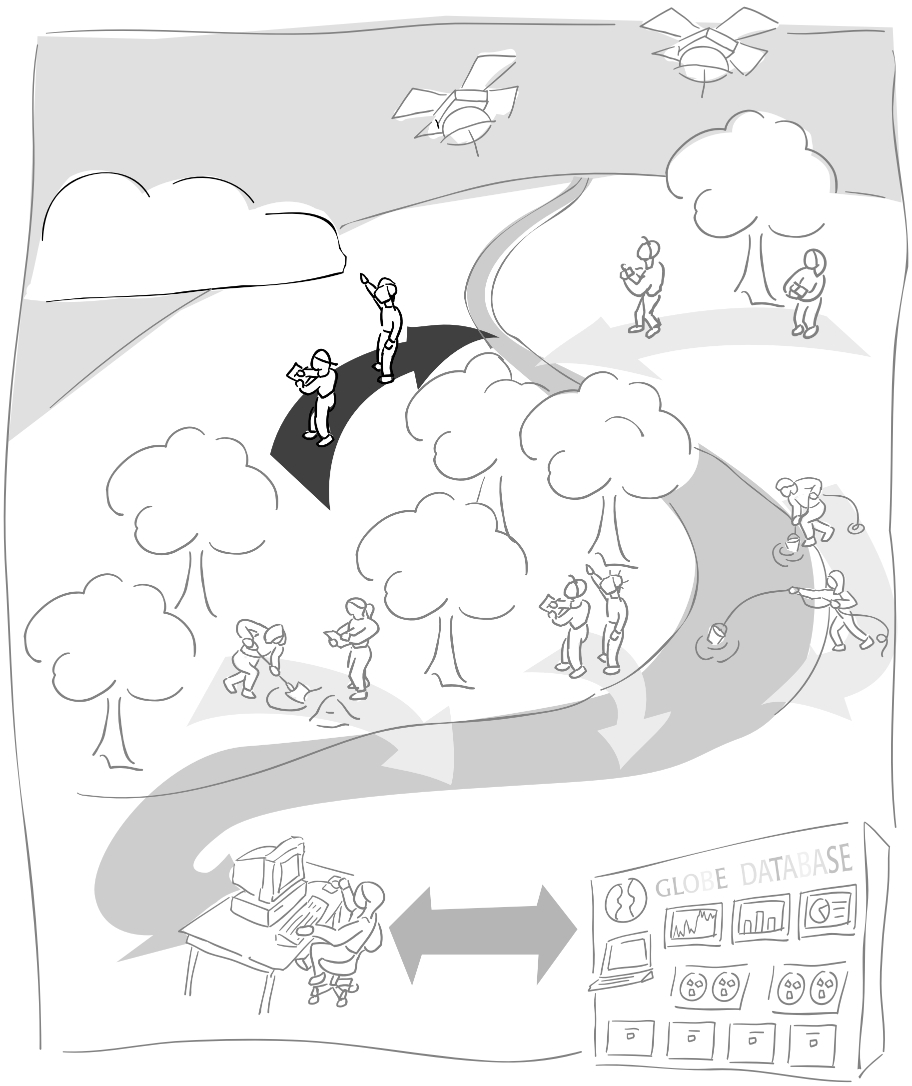
Atmosphere Investigation



A GLOBE™ Learning Investigation

Atmosphere Investigation at a Glance

Protocols

Daily measurements within one hour of local solar noon of:
- cloud type
- cloud cover
- precipitation (rainfall or snowfall)
- precipitation pH
- current temperature
- maximum temperature within the last 24 hours
- minimum temperature within the last 24 hours

Suggested Sequence of Activities

Read *Welcome to the Atmosphere Investigation*.

Copy and distribute the scientist letter and interview to your students.

Read through *Protocols* to learn precisely what is to be measured and how.

Read the brief description of the learning activities at the beginning of the *Learning Activities* section.

Do these activities with your students before beginning the protocols:
- *Observing, Describing, and Identifying Clouds*
- *Estimating Cloud Cover: A Simulation*

Install the instrument shelter and the rain gauge in a suitable location on the school grounds. If possible, you should involve your students in planning the location of the instruments. Criteria for placement of the instruments are given in *Protocols*.

Submit your Atmosphere Study Site definition data to the GLOBE Student Data Server.

Make copies of the Atmosphere Data Work Sheet in the *Appendix*.

Teach students how to take the daily measurements, following the instructions in the protocols.

Submit your data every day to the GLOBE Student Data Server.

Do the remaining learning activities as you continue daily measurements.

Special Notes

Make sure you get the instruments required for the Atmosphere protocols. Information on how to obtain these instruments is in the *Toolkit*.

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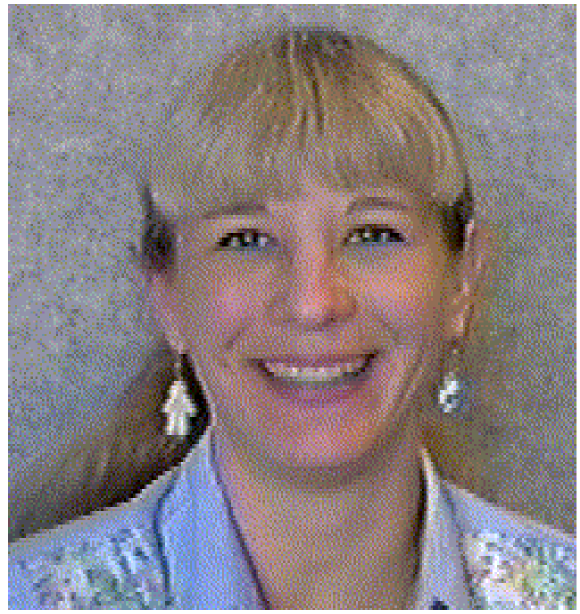
Scientist's Letter to Students

Duplicate and distribute to students.

Dear Students,



Hello! My name is Susan Postawko, and I'm the lead scientist for the Atmosphere and Climate investigations for GLOBE. I'm on the faculty in the School of Meteorology at the University of Oklahoma in Norman, Oklahoma. My partners in the Atmosphere and Climate group here in Oklahoma are Dr. Mark Morrissey, Ms. Renee McPherson, Dr. Ken Crawford, and Dr. Rajeev Gowda. In addition, we have several undergraduate and graduate students working with us. We're very pleased to welcome you to the Atmosphere and Climate investigations, and we're looking forward to working with you.

Nearly everyone on our planet is interested, at some level, in climate and climatic change. This is because any long-term change in temperature or precipitation around the globe will ultimately affect us all. Many countries are implementing education, information, and training programs to increase awareness of the potential impacts of climate change. In order to detect long-term trends, we must improve our monitoring of the global climate.

By making your daily cloud, temperature, and precipitation measurements, you are helping to keep a finger on the pulse of our planet. You are involved in monitoring changes that take place around the world. This is a big responsibility, but one that we are confident you can handle.

When you measure environmental parameters and share your data with students worldwide, you are gaining the knowledge and skills to make choices that will determine what kind of world we leave for future generations.

We will keep you updated on what scientists are learning about our weather and climate, and invite you to send us information about any discoveries you may make!

Again, welcome to GLOBE! And have fun!

Susan Postawko

Dr. Susan Postawko
University of Oklahoma
Norman, Oklahoma, USA

Meet Dr. Susan Postawko

Duplicate and distribute to students.

Dr. Postawko: I'm an assistant professor in the meteorology department at the University of Oklahoma in Norman, Oklahoma. I'm interested in weather around the world as well as on other planets, particularly Mars. I study what happened on Mars during the early history of the solar system and compare it to what Earth might have been like.

GLOBE: Mars has weather?

Dr. Postawko: Mars has an atmosphere and any planet with an atmosphere has weather. Its atmosphere is about 1/100th as thick as Earth's atmosphere and its average temperature is below freezing. But when we look at Mars through telescopes, we see cloud patterns that look like cloud patterns on Earth. Shortly after Mars was formed, about 4 billion years ago, it may have been a lot like Earth. We see what look like dried-up river beds on Mars and other indications that water once flowed on its surface. Maybe as recently as three billion years ago, Mars may have been more like Earth. One of the things I'm interested in is if Mars and Earth started out alike, why did they become so different?

GLOBE: In our solar system does liquid water exist anywhere else other than Earth?

Dr. Postawko: Maybe on Europa, one of Jupiter's moons. There's compelling evidence that underneath an icy crust, which may be tens of meters thick, there is liquid water on Europa. The reason we think there is liquid water is because Europa is incredibly smooth. Most things in the solar system are pockmarked with craters, but Europa, from what we could tell from the Voyager fly-bys, has a relief of maybe a couple of meters. That's about it. It looks as though when anything higher than that forms on Europa, some liquid from the interior flows upward and fills it in, and since it's icy on the surface, it's pretty certain that the liquid is water.

GLOBE: So it's kind of like a billiard ball in terms of its surface.

Dr. Postawko: Yes. The solar system's a fascinating place. You see some of these other places and you ask, 'Wow! How did this happen?'

GLOBE: What kind of data do you want GLOBE students to collect and why?

Dr. Postawko: I'm interested in rainfall and clouds because they affect the amount of sunshine that comes in – the sun provides the energy for the whole planet. This is what drives life. We need to know how much sunshine is coming in and what kind of clouds might be reflecting sunlight away. The clouds also tell us about how much water vapor is in the atmosphere and that helps us understand the hydrologic cycle, probably the most critical cycle on Earth. How much water is evaporating from the surface? How much water is in the atmosphere? How much precipitation is there at any point, at any given time?

Everybody talks about global warming these days. The jury is still out on exactly what we are doing to the atmosphere, but the truth is the climate of Earth has always changed. There have been times when it was colder and when it was warmer. We need to understand those changes so we can adjust when new changes come. Are we going to have a new ice age? What's that going to mean about where people can live or the crops we can grow?

GLOBE: *You can identify the trends, but can you identify what causes them?*

Dr. Postawko: Not always. The Earth is a complex system and scientists must know a little of everything—atmospheric science, oceanography, geology, biology, and everything else—to really understand what's causing any one thing to change. For a long time, scientists studied only in their own little niches. It has only been recently that we realized we can't really understand the Earth in parts. So it is more difficult to identify what's causing trends. It seems the precipitation trend probably has to do with the planet getting a little warmer. But then you can ask, 'Well, what's causing it to get a little warmer?' Maybe carbon dioxide is increasing in the atmosphere. Or maybe it's something else.

GLOBE: *Has there been any progress about changing the weather? Making it rain a little more over deserts, for example?*

Dr. Postawko: That's a controversial topic. From the beginning of our awareness of weather, people have tried to change it. We've tried cloud-seeding to make it rain. We've tried seeding hurricanes to help them die out before they hit land. The truth is that in most instances we don't know if what we're doing has any effect. We don't know if seeding clouds really helps them to rain or if they would have rained anyway.

GLOBE: *Have students helped scientists collect this kind of data?*

Dr. Postawko: Absolutely. We're involved in a program where students around the Pacific have been taking rainfall measurements for the last three years. In the Pacific, there's a lot of ocean and not a whole lot of land, so any data we can get from students is invaluable in helping us understand the changes in temperature and precipitation around the region. In fact, students probably make almost 30% of all of the observations that are made around the Pacific.

GLOBE: *Tell us a little about yourself. Where were you born? Where did you grow up?*

Dr. Postawko: I grew up in St. Louis, Missouri and went to college at the University of Missouri in St. Louis. I was really interested in astronomy, so I went into the physics and astronomy program. I was amazingly unprepared to do that! My high school didn't have an extensive math and science curriculum. I'd always liked science, but I never liked math a lot. In college, I saw the applications of math in science and got excited. I enjoyed it to the point where I became a teaching assistant in math, which I never would have dreamed of doing! I ended up getting a bachelor's degree in physics and astronomy. My interest in astronomy focused on planets. As I contemplated graduate school, one of my professors told me to consider atmospheric science programs because they do planetary atmosphere work. Sure enough, I went to the University of Michigan in atmospheric science. I got my Ph.D. in 1983, and then studied the evolution and atmospheres of planets at the University of Hawaii. In 1991, my husband and I came to the University of Oklahoma and now I'm in a very traditional meteorology department, which is fun. As soon as the weather turns bad, everybody runs to their cars to chase tornadoes.

GLOBE: *You chase tornadoes?*

Dr. Postawko: They chase tornadoes. I still have this urge to go into the cellar when there's bad weather. Everybody else here runs to their cars. The graduate students are threatening to drag me out with them one of the these days. Everybody and his dog has a video camera. I'll watch it on TV.

GLOBE: *What happens when a tornado starts chasing you?*

Dr. Postawko: Then you have basic problems.

GLOBE: *Do you have any children?*

Dr. Postawko: No, but I have four dogs, five cats and three birds.

GLOBE: *What do you do for fun?*

Dr. Postawko: A lot of my fun tends to be in science. I like to go out in the evenings with binoculars and look at the constellations, watch for shooting stars, try to find the planets. My idea of fun has changed dramatically since we've moved to Oklahoma. In Hawaii, I liked hiking, kayaking, and scuba diving. Not much scuba diving in Oklahoma. But, it's an interesting state otherwise.

GLOBE: *You became interested in astronomy in high school?*

Dr. Postawko: I've been interested in astronomy for as long as I can remember. I think in part it was because my dad was interested in looking at the constellations. He'd read to me about planets and things.

GLOBE: *What were your attitudes towards science in middle school and high school?*

Dr. Postawko: I enjoyed science. I struggled through math because I didn't

understand its usefulness. At college, I got a little blue-haired lady for an advisor. When I told her that I wanted to major in physics and astronomy, she said, 'Honey, you know that takes a lot of math.' 'Okay, I guess I'll take a lot of math if that's what I have to do.' She thought I wanted to major in Spanish because I took Spanish in high school. 'No, I don't think I want to major in Spanish.'

GLOBE: *As a woman, did anyone try to discourage you from pursuing science?*

Dr. Postawko: Only that advisor. I don't think she had many women in science. The truth is when I hear women talk about the obstacles they were up against, I really admire them for continuing because I never perceived anybody trying to keep me from doing what I wanted to do. My parents always encouraged me to do what I wanted to do. I had marvelous professors who never implied that I should do something else instead of science.

GLOBE: *If a genie suddenly appeared out of a lamp and offered to answer any question, what would you ask?*

Dr. Postawko: What was early Mars like? I've spent years trying to figure that out.

GLOBE: *Can we find out without actually going there, or do we have to go there and do some digging?*

Dr. Postawko: I think ultimately it's going to mean going there. Part of the problem with sending remote instruments is that they can't see something that looks unusual and test it. One of the ways we learned so much about the moon was the astronauts there could actually look around and determine what to study.

GLOBE: *As a scientist, do you recall the greatest challenge that you met?*

Dr. Postawko: The fascinating thing about science is that almost every day you're doing something that no one else has done before. You're learning new things that no one else has learned before. The exciting thing about science is not just big discoveries that you might be fortunate enough to stumble upon, but that every day you're adding to knowledge.

GLOBE: What are the rewards of science?

Dr. Postawko: I think there are two things in science that can be gratifying. The first is finding out things that help people in their daily lives. Look around at the technologies we use daily. They're offshoots of somebody's science research. There is also gratification in learning and adding to the knowledge about the Earth, the planets, and the universe. You never know what information might help a future generation. When Isaac Newton was coming up with calculus or the theory of gravity, I don't think he really knew how it would be applied in later generations, but now we use that to send spacecraft to Jupiter.

GLOBE: When you were growing up, did you have heroes?

Dr. Postawko: Astronauts. I wanted to be an astronaut. I thought they were the coolest people around.

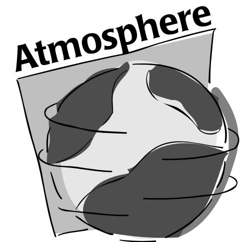
GLOBE: Do you have any advice for students who are interested in Earth science?

Dr. Postawko: Have confidence in yourself. Do what you want to do. Don't let anybody tell you that you're not smart enough to do something, because if I can get through this, anyone can. You have to follow your heart, you have to follow what you're interested in doing. If you really put your mind to it, you can do it. That sounds corny, and if somebody had told me that as an eighth grader, I would have said, 'Yeah, right, sure. You don't know what it's like.' But it really is true.

GLOBE: Do you have anything else you want to add?

Dr. Postawko: I hope that students do not think that scientists sit in ivory towers with no connection to the real world. The real world is science. Science is like a mystery novel. You're always looking for answers. Why did this happen and why did that happen? Students should have fun with science.

Introduction



The Big Picture

"Everybody talks about the weather but no one does anything about it!" This is an old cliché that has been a complaint of people all over the world, probably for centuries. Actually, someone is doing something about the weather. Scientists around the world are studying the weather everyday, and now through GLOBE, your students can help! The measurements they make will help us better understand our planet's climate.

There are many reasons why we study the atmosphere. On a day-to-day basis we want to know things like what the temperature will be so we can decide what type of clothes to wear; whether we need to take an umbrella with us when we go outside; or if we need to wear a hat and sunscreen to protect us from the sun's ultraviolet rays. Farmers need to know if their crops will get enough rain. Ski resorts need to know if enough snow will fall. People in areas struck by hurricanes would like to know how many hurricanes to expect in a given year. Nearly everyone would like to know what the weather is going to be, not only tomorrow or the next day, but six months, a year, or even ten years from now! Atmospheric scientists study not only what is going on with the world's weather today, but why it was a certain way in the past and what it will be like in the future.

By *weather* we mean what is happening in the atmosphere today, tomorrow, or even next week. By *climate* we mean weather over time. For example, in a certain city the current temperature may be 25° C (this is weather), but if we were to look at the weather records for the past 30 years we might find that the average temperature in that city on that particular day is 18° C (this is climate). We also might find that over this 30 year period the temperature in this city has ranged from as high as 30°C to as low as 12°C on that particular day. Therefore, the present temperature of 25°C is not unusual.

When we study the history of Earth's climate, we notice that temperature and precipitation in any given region change over time. For example, images from certain satellites show that great rivers used to run through the Sahara Desert. We also believe that ice caps once covered parts of Africa and that a shallow sea covered much of the United States. All of these changes happened long before people lived in any of these regions. If Earth was so different in the past, can we predict what might happen in the future?

Earth's atmosphere is a thin layer of gases made up of about 79 percent nitrogen, 20 percent oxygen, and 1 percent of a number of other gases (including water vapor and carbon dioxide). The atmosphere is quite active and changes in one part of the world are likely to result in changes in other areas. Many scientists are concerned that burning fossil fuels, such as coal and oil, puts so much carbon dioxide into our atmosphere that it may warm the entire planet. Burning also adds particles called *aerosols* to the atmosphere and locally these aerosols can more than offset the warming effects of carbon dioxide and other gases. Burning fossil fuels can also increase the amount of gases such as sulfur dioxide and nitrogen oxides in the atmosphere. Increases in these gases have been linked to increasing acidity of precipitation, which can affect plants, animals, water supplies, soils, and structures. Although Earth's climate varies naturally, humans have the potential to affect the climate at a much faster rate than natural changes take place.

The consequences of climate change potentially could affect every living thing on our planet. International communication and cooperation is vital to understanding and coping with the possible effects of global climate change. Measurements of environmental parameters are necessary to monitor the present state of the atmosphere and alert us to any changes that might be taking place. Through the GLOBE program, students will help scientists to understand environmental conditions on Earth today and over time, to determine if there are any changes.

People often think that scientists know what is happening in all parts of the world, but this is far from true. There are many regions where scientists have only the most general understanding of environmental factors such as temperature and precipitation. Even in regions where there seems to be an abundance of data, scientists still do not know how much these factors vary over relatively short distances. The measurements that students make through the GLOBE program will go a long way in helping everyone understand more about the world.

A Field View of the Atmosphere Investigation

Although there are many aspects of the atmosphere that are important to understand, the fundamental measurements on which we will focus are cloud type and cover, air temperature, and precipitation amount and pH. A great habit to develop is looking up at the sky every time you go outdoors. Start to pay attention to what is going on in the atmosphere. You might be surprised at how much is happening!

Students will make cloud observations with their eyes. One quantity they will estimate is cloud cover, which ranges from zero (a totally clear sky) to 100 percent (a completely overcast sky).

Another characteristic students will determine with their eyes is cloud type. Scientists have defined classes of clouds based on their appearance and their altitude. Students may already be familiar with some cloud types, like tall thunderclouds called cumulonimbus, or the wispy ice clouds high in the sky called cirrus. With the help of the GLOBE cloud chart, students will categorize each cloud as one of ten types.

The basic instrument for measuring temperature is the thermometer, of which there are many types. Special thermometers are available that register maximum and minimum temperatures, that is, the highest and lowest temperatures since the last time the thermometer was reset. To measure the temperature of the air, a thermometer should be located in a well ventilated place out of direct sunlight and away from local sources of heat.

Precipitation is relatively easy to measure. The rain gauge is a simple container to catch rainfall, combined with some means for determining how much water has accumulated in it. It is important that the gauge be located in an area that is not blocked by buildings or covered with trees, as these would influence the amount of rain that could fall into your gauge. In regions where snow falls, snow depth can be measured with a meter stick. Water content varies greatly from snowfall to snowfall, and therefore it also needs to be measured. The pH of rain water or melted snow can be measured using pH paper, a pH pen, or a pH meter, depending on the level of the students.

Prior to the actual placement of the instruments used in this investigation, read the section on instrument placement in the Protocols section. Then, with your students, take a walk around the school grounds to locate the best places to site the instruments. This activity will help assess the students' initial knowledge and will get them thinking about the factors that can influence their measurements.

Good questions to help get the students started on determining the best places to take their measurements would be:

- Where on the school grounds would you see the most clouds? Where would you see the least?
- Where on the school grounds would the temperature be the highest? Why? Where would temperature be the lowest? Why? Are either of these two areas representative of the entire school grounds?
- How could buildings affect the temperature?
- Would there be a difference in temperature between a grassy field and a paved parking lot or playground? Why?
- Where would you put a rain gauge to catch the most rain? Why? Is this the same place where you would place a board to catch the most snow?

As you walk around the school grounds, have the students draw a map of the area. The youngest students could just sketch the main features, such as the school building(s), parking lots, playgrounds, etc. Older students should fill in more detail, such as what the playground surface is (e.g. paved, grassy, or bare ground). Have them note any streams or ponds and indicate areas of trees. They could measure the heights of buildings and trees using the clinometer and techniques given in the *Land Cover/Biology Investigation* and note these on their maps. The goal is to have a drawing of the school grounds so that when you decide where to place your meteorological instruments, students can locate them on their map. This will allow the students to give a good physical description of the area surrounding their instruments. In subsequent years, the new class of students can repeat this mapping to understand why the specific locations were chosen.

Focusing on the Key Science Ideas

In this section we will look more closely at the scientific importance of each of the atmospheric measurements that will be made as part of the GLOBE program.

Clouds

Water is present in the atmosphere in the form of gas (water vapor), liquid (rain drops or cloud droplets), and solid (ice crystals or frozen rain). Like most other gases that make up the atmosphere, water vapor is invisible to the human eye. However, unlike most other gases in our atmosphere, under the right conditions water vapor can change from a gas into solid particles or liquid drops. If temperatures are above freezing, the water vapor will condense into cloud droplets. If temperatures are below freezing, as they always are high up in the atmosphere, tiny ice crystals will form instead. Clouds are simply the visible form of these crystals or droplets.

Which types of clouds you see often depends on the weather conditions you are experiencing or will soon experience. Some clouds form only in fair weather, while others bring showers or thunderstorms. The types of clouds present provide important information about vertical movement of the atmosphere at different heights. By paying attention to the clouds, soon you will be able to use cloud formation to forecast the weather!

Everyone is aware of clouds, but not everyone is aware of their importance to weather and climate. Clouds play a complex role in the climate system. They are the source of precipitation, affect the amount of energy from the sun that Earth absorbs, and insulate the Earth's surface and lower atmosphere. At any given time, about half of Earth's surface is shadowed by clouds. Clouds reflect some of the sunlight away from Earth, thus keeping the planet cooler than it would be otherwise. At the same time, clouds also absorb some of the heat energy given off by the Earth's surface and release some of this back toward the ground, thus keeping the surface warmer than it would be otherwise. Satellite measurements have shown that, on average, the cooling effect of clouds dominates over their warming effect. Scientists calculate that if clouds never formed in Earth's atmosphere, our planet would be nearly 30° C warmer on average.

Question for discussion: Find out the average number of sunny days in each month for your area, as well as the average temperature for each month (consult an almanac or similar reference book, or conduct a search on the World Wide Web; after the first year, use your GLOBE data as well). How do students think the temperature of your area would be affected if the number of sunny days increased or decreased?

Precipitation

Another vital measurement students will make is *precipitation*. Precipitation refers to all forms of liquid or solid water that fall from the atmosphere and reach Earth's surface. *Liquid precipitation* includes rainfall and drizzle, *solid precipitation* includes snow, ice pellets, hail, and freezing rain.

Our planet is a water planet. In fact, it is the only planet in our solar system where liquid water naturally flows on the surface. Nearly all life depends on water. The water that ends up in the atmosphere, only to be returned to Earth's surface, is a part of the larger *hydrologic cycle*. In this cycle, water evaporates from the oceans and land, passes through the atmosphere, falls to the surface as precipitation, and returns to the sea from the land through rivers and other paths.

Precipitation is a vital component of climate. Where it is scarce, deserts occur. Where it is abundant, there is luxurious plant growth. Water sustains life. Precipitation is critical to agriculture, fresh water supplies, and, in some regions, power supplies.

One of the key roles of water on Earth is to transfer heat from the *tropics* to higher latitudes. This is done both by the movement of ocean waters (currents) and by the movement of water in the atmosphere. As energy from the sun reaches Earth's surface, it is more intense near the equator than it is near the poles. That is the main reason why it is warm in the tropics and cold in the Arctic and Antarctic.

Much of the sun's energy in the equatorial regions is absorbed by oceans, causing water to evaporate. This water vapor is now free to move in the atmosphere. As it moves upward or towards higher latitudes, the water vapor encounters colder temperatures, and it begins to condense (change from a gas to a liquid) and form clouds and precipitation. When water changes from a gas to a liquid, it releases heat into the atmosphere. In other words, through the transformation of water from a liquid to a gas, then back to a liquid in the atmosphere, some of the sun's energy is transported from the equatorial regions towards the polar regions.

By knowing where clouds form, and where, when, and how much precipitation falls, scientists can better understand where energy is being released or absorbed in Earth's atmosphere. This, in turn, helps scientists understand the behavior of Earth's atmosphere.

Question for discussion: Find out the average amount of precipitation in your area for each month (consult an almanac or similar reference book, or conduct a search on the World Wide Web; once you have GLOBE data for at least a year, include this as well). What do you think would happen if all the precipitation occurred in just one month? What would be the consequences if the rain were evenly distributed throughout the year? What if you got only half the amount of rainfall in a given year? What if you got double the amount of rainfall? What factors do you think influence where and when rain falls?

Precipitation pH

Water moves through every living plant and animal. The chemical composition of the water, therefore, will affect all terrestrial and aquatic ecosystems. Although normal precipitation is slightly acidic (pH of about 5.6) due to the gases which naturally comprise Earth's atmosphere, burning of fossil fuels releases gases into the atmosphere which interact with water vapor and form precipitation with pH below 5.6. This *acidic precipitation* can directly harm plants over a long period, but its most serious effect is weakening plants so that they become more susceptible to stresses such as cold, disease, insects, and drought. Acidic precipitation leaches nutrients out of the soil and also can release from the soil soluble aluminum ions which damage tree roots. If these aluminum ions are washed into lakes and streams they can harm many kinds of fish.

In addition to adversely affecting life forms, acid precipitation does great harm to structures. Acid precipitation is known to enhance corrosion of metals and contributes to the destruction of stone structures and statues. In many regions of the world, famous buildings and sculptures are deteriorating at increased rates.

The acidity or pH of water can change as it moves through the environment. When water first condenses in the atmosphere, its pH is neutral or 7.0. Then, gases such as carbon dioxide and particles from the atmosphere dissolve in the water droplets, usually lowering the pH. As water flows over the land surface or through soil, the pH is changed by chemical interactions with the land. The water then comes together in streams, rivers, lakes, and eventually the oceans. In GLOBE, students measure the pH of precipitation, soil, and surface water.

Temperature

When we think of the difference between day and night, between winter and summer, or between the climate of a tropical region compared to a polar region, we can easily imagine these differences in terms of temperature.

Many factors affect temperature. One of the most important factors is latitude. Scientists studying the climate of our planet are very interested in finding out if the temperature at different latitudes is changing, and if so, is it changing in the same way at all latitudes? Most computer models of Earth's climate predict that if Earth warms then the polar regions will warm more than the tropics (although the polar regions will always remain colder than the tropics).

Together, temperature and precipitation have an important impact on the types of plants and animals that live in a certain area, and even on what kind of soil forms there. The measurements that students make for the GLOBE Atmosphere Investigation are important to scientists who study weather, climate, land cover, biology, hydrology, and soil.

Questions for discussion: Find out the average temperature for your area for each month (consult an almanac or similar reference book, or search the World Wide Web; once you have GLOBE data for at least a year, include this as well). Is there a variation in temperature from month to month? If so, why do you think this happens? Do you think that all places at your same latitude experience the same temperature? Why or why not? What factors do you think most affect the temperature in your area?

Preparing for the Field

Choosing the location for your Atmosphere Study Site and setting up your rain gauge and thermometer shelter at this site will be your single most time-consuming task in this investigation. See the *Protocols* for complete instructions on choosing the site and proper placement of the instruments. Daily readings of precipitation amount and temperature typically will take less than 10 minutes (perhaps a bit longer for the youngest students who may need more time to study the numbers). The cloud observations may take 5 minutes or so per day, depending on how much class discussion there is on the cloud cover and cloud types. Expect the cloud observations to take longer when the students are first learning how to take them. Again, the youngest students may need more time. Depending on the method used to take precipitation pH measurements, this protocol will take from 5 to 15 minutes (longer if the pH pen or meter has not been calibrated recently).

All of the atmospheric science measurements need to be taken on a daily basis, as close to the same time of day as possible, to ensure easy comparison of measurements made around the world. For GLOBE, all atmospheric observations should be made within one hour of local solar noon, and the rain gauge should be emptied and the thermometer reset during this two hour period as well. See the box on how to calculate solar noon. Does this mean that only classes that meet at that time can participate? NO! Because these measurements do not require much time to take, students from classes that meet earlier or later in the day can be assigned to take the measurements during their lunch break. The key is consistency in the time of day the measurements are taken.

A single student can read the rain gauge and the thermometer. However, it is a good idea to have a small group of students take these readings so they can check each other. Readings could either be taken by the group as a whole, or readings could be made individually and then compared. If the readings are made individually, the group must remember to empty the rain gauge and reset the thermometer when they are finished. Rotating groups through the class (or classes) on a daily or weekly basis will give all students an opportunity to participate. Having multiple groups take measurements at different times on the same day is discouraged because it opens the door to confusion in emptying the rain gauge, resetting the thermometer, and reporting the data. Remember that when GLOBE gets a second data report for the same Atmosphere Study Site on the same day, the second report is viewed as a correction and replaces the first one.

The estimates of cloud type and cloud cover are *subjective* measurements, so the more students involved in this task, the better. Each student should take his or her own readings; then, students should come to an agreement as a group. Do not be surprised if your students initially have difficulty with these estimates. Even seasoned weather observers debate which type of cloud they are seeing, or exactly how much of the sky is covered by clouds. As your students get used to these observations, they will begin to recognize the subtle differences in cloud types.

How To Calculate Solar Noon

Solar noon is the time when the sun appears to have reached its highest point in the sky during the day. Solar noon is the term used by GLOBE. An astronomer, for example, would refer to the same time as local apparent noon. Solar noon generally is not the same as "clock noon," and depends on your location within your time zone. Solar noon does occur, however, half-way between your local sunrise and sunset. Therefore, an easy way to calculate your local solar noon is to find a newspaper from a nearby town that gives sunrise and sunset times. Take the average of these times to find solar noon. First, convert all your times to 24-hour clock times by adding 12 to any pm times, then find the average of the sunrise and sunset times. (Add the two times and divide by two.) This is the time of solar noon.

Example:	**1**	**2**	**3**	**4**
Sunrise (am or 24-hour clock are the same)	7:02 am	6:58 am	7:03 am	6:32 am
Sunset	5:43 pm	5:46 pm	8:09 pm	5:03 pm
Sunset (24-hour clock)	17:43	17:46	20:09	17:03
Sunrise + Sunset	24 hr 45 min	23 hr 104 min	27 hr 12 min	23 hr 35 min
Equivalent (so that the number of hours is even)	(unchanged)	24 hr 44 min	26 hr 72 min	22 hr 95 min
Divide by 2	12 hr 22.5 min	12 hr 22 min	13 hr 36 min	11 hr 47.5 min
Local Solar Noon (rounded to the nearest minute	12:23 pm	12:22 pm	1:36 pm or 13:36	11:48 am

Overview of Educational Activities

Student Learning Goals

Within GLOBE, students can enhance their education through involvement in hands-on, scientifically valid research. Student learning goals for this module are:

- To observe and measure weather and climate-related phenomena accurately and objectively,
- To design and test students' own weather instruments as a way of understanding how standard instruments work,
- To classify objects and events based on similarities, differences, and interrelationships,
- To solve problems by experimentation,
- To interpret collected data and come to sound conclusions,
- To explore and understand the uncertainties inherent in any scientific measurement,
- To communicate information learned through their scientific investigations, and
- To develop models from data, patterns, or relationships.

Concepts

The concepts which are covered in the protocols and learning activities of this investigation are:

Composition of the atmosphere
Cloud formation
Condensation
Cooling and warming effects of clouds
Clouds are identified by their shape, altitude, and precipitation characteristics
Relationship of clouds and changes in clouds to weather
Effects of wind on precipitation measurement
Change of state
Density of snow
Factors affecting the pH of precipitation
Temperature
Heat
Convection
Conduction
Radiation
Heat transfer through radiation, conduction, and convection
Conduction and convection are two key forms of heat transfer
Different substances, such as soil, water, and air, transfer energy and heat at different rates
Heat capacity
Substances expand and contract as the temperature changes
Liquid-in-glass thermometers work on the basis of thermal expansion and contraction
Using a simulation to explore the accuracy of observations
Meniscus reading

Student Assessment

Students should be assessed using formative and summative evaluation methods, which may be either qualitative or quantitative in nature. Such methods should reflect the development level of your students. Various tools should be used to assess the growth of students in the following areas:

- concept mastery
- use of science process skills
- attitudes toward science, science classes, and science careers
- higher level skills, including questioning, identifying cause and effect, and predicting
- applying concepts and process skills in new situations

One way to assess students' understanding of the content and processes within the Atmosphere Investigation is to monitor the daily data that students record and submit. Is the maximum temperature recorded always greater than the minimum temperature? Is the current temperature recorded equal to or between the maximum and minimum for the past 24 hours? In both instances, the answer should be yes. If it is not, you should suspect that either the students do not know how to read the maximum/minimum thermometer or they are unsure of what they are reading.

Another way to assess students' understanding of the protocols is to ask them to choose the optimum placement for instruments when presented with a variety of situations. What if your school were in a city? What if it were in a heavily wooded area?

The learning activities in this module are designed to help students understand the protocols and the instruments used to implement the protocols. They also allow you to assess students' understanding of key concepts and skills. Students may keep a log of their activities, give oral reports to the class (or maybe even weather reports to the school!), and write papers that could be reviewed by other students.

Skills

The skills covered in the protocols and learning activities of this investigation are as follows:

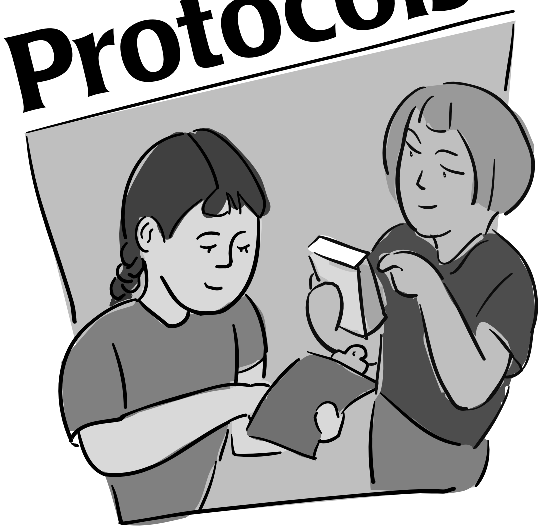
Broadly Applicable Science Skills

Observing carefully
Observing systematically over a period of time
Measuring
Reading a scale accurately
Collecting and *recording* data
Conducting an experiment
Constructing an apparatus for an experiment
Hypothesizing and *predicting*
Designing experiments
Organizing data in tables
Analyzing data
Graphing
Correlating one observed phenomenon with another
Communicating experimental results orally and in writing
Communicating mathematically
Working effectively in a group

Specific Skills Associated with the Atmosphere Investigation

Estimating simulated cloud cover
Estimating cloud cover
Observing and *describing* the appearance of clouds
Estimating cloud height
Identifying the ten major cloud types
Recording and *organizing* cloud data in the GLOBE Science Notebook
Using a rain gauge
Using a thermometer
Using pH measuring equipment

Protocols



All of the measurements below should be taken daily within one hour of local solar noon.

Cloud Type Protocol

Students will determine the types of clouds in their skies.

Cloud Cover Protocol

Students will determine the cloud cover in their skies.

Rainfall Protocol

Students will use a rain gauge to determine liquid precipitation at their study site.

Solid Precipitation Protocol

Students will measure snow and other forms of solid precipitation at their study site.

Precipitation pH Protocol

Students will measure the pH of rainfall and melted snowfall at their study site.

Maximum, Minimum, and Current Temperatures Protocol

Students will measure air temperature at their study site.

How to Perform Your Atmosphere Investigation

Study Site for the Investigation

Locate the Atmosphere Study Site on or near your school grounds so students can have daily access to them. The precipitation measurements should be taken within 100 meters of the soil moisture measurements described in the Soil Investigation.

Cloud Observation

Measurements of cloud amount and cloud type require an unobstructed view of the sky. The middle of a sports field would be an excellent location. The site where you take your cloud measurements does not have to be in the exact location of your rain gauge and thermometers. To pick a good spot from which to take cloud measurements, simply walk around your school until you come to an area where you have the most unobstructed view of the sky.

If you live in a city, you may not be able to find a completely unobstructed view of the sky. To test whether the site you pick is a good one, ask yourself what would happen if the parts of the sky you cannot see were completely cloud covered or completely clear. Would this make a difference in the measurements you report? A site is satisfactory if a small portion of the sky is blocked, as long as that portion would not change the measurements you report.

Instrument Placement

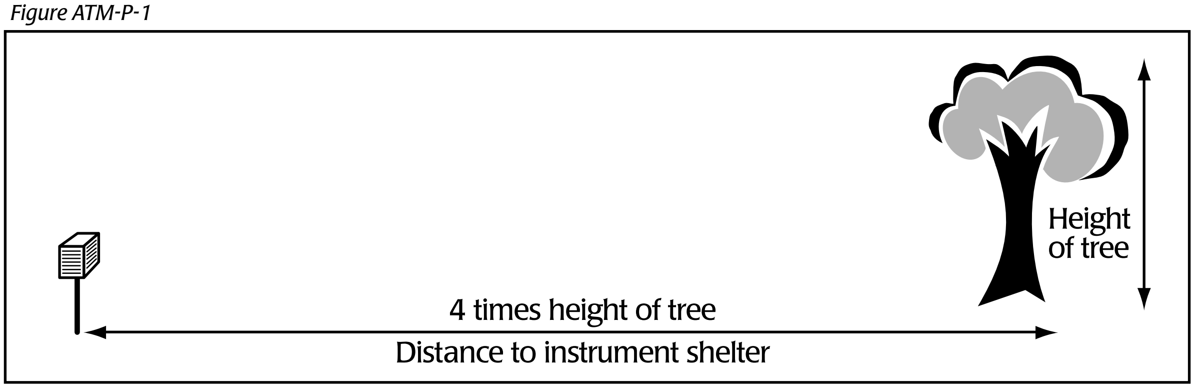
The ideal placement for both the rain gauge (and/or snowboard) and the instrument shelter, which will house the thermometers, is a flat, open area with a natural (e.g., grassy) surface. Avoid building roofs and paved or concrete surfaces if at all possible; these can become hotter than a grassy surface and affect temperature readings. Hard surfaces can cause errors in precipitation measurements due to splash-in. Also avoid placing the instruments on steep slopes or in sheltered hollows unless such terrain represents the surrounding area.

Do not place the rain gauge and instrument shelter close to buildings, trees, or high bushes. Nearby objects can block the flow of air to the thermometers and affect the amount of rain that collects in the rain gauge.

Ideally the rain gauge and the instrument shelter should be placed four times as far from an object as that object is high. For example, if your site is surrounded by trees or buildings that are 10 meters tall, place your instruments at least 40 meters from these trees. See Figure ATM-P-1. At such distances, trees, bushes, or buildings can break the wind and actually make your rainfall readings more accurate.

The instruments may be placed on a single post with the rain gauge on the opposite side from the shelter and above it, so that the instrument shelter

Figure ATM-P-1



does not block rain from collecting in the rain gauge. However, wind is one of the greatest contributors to errors in rain gauge measurements (wind blowing across the top of the gauge creates an effect that causes raindrops to be deflected around the gauge), and where possible, it is best to place the gauge as low to the ground as practical. This requires that the rain gauge be mounted on a separate post 3 to 4 meters away from the instrument shelter so that the instrument shelter does not block rain from collecting in the gauge. The instrument shelter should be mounted on the side of the post away from the Equator (i.e. on the north side in the Northern Hemisphere and on the south side in the Southern Hemisphere).

Your students should draw a map of the locations of the instruments. Include their placement relative to nearby buildings, trees, and shrubs using north-south coordinates as well as their distances to these objects. Also note the type of surface on which the instruments are placed. If it was not possible to locate your instruments as far from buildings, trees, or shrubs as requested or if the area around the instrument shelter is not a grassy natural surface, information about the relative locations of possible obstructions and about the surface material should be reported to the GLOBE Student Data Server as part of defining your Atmosphere Study Site.

Snowboard Placement

Place the snowboard on relatively level ground where the snow depth best represents the average depth of the surrounding area. For a hillside, use the slope with an exposure away from the sun (this means a northerly exposure in the northern hemisphere and a southerly exposure in the southern hemisphere). The site should be free from trees, buildings and other obstructions that may affect wind flow or the melting of snow.

Determine Location

Once you have chosen the site for the instruments, determine its coordinates with the GPS receiver and submit your findings to the GLOBE Student Data Server.

There may be no such thing as an ideal location for the atmospheric instruments on your school grounds. In this case, make every effort to place the instruments in as good a location as possible, and report all derivations from the specified ideal (e.g. only 20 m away from 30 m tall trees, instrument shelter is set up over asphalt).

Note: Some schools may prefer to use automated instruments to measure temperature. Information about the instruments used must be reported to the GLOBE Student Data Server as part of defining your Atmosphere Study Site Automated instruments require periodic recalibration. If your school uses an automated instrument, you must check its accuracy monthly by comparing it to the readings produced by an instrument which meets the GLOBE Instrument Specifications and which is located as close as possible to the sensors of your automated system.

Cloud Type Protocol

Purpose
To observe cloud type at the school's Atmosphere Study Site

Overview
Cloud type is useful in climate studies and is related to precipitation and air temperature.

Time
5 minutes

Level
All

Frequency
Daily within one hour of local solar noon

Key Concepts
Cloud formation
Composition of the atmosphere
Cooling/warming effect of clouds

Skills
Identifying cloud type
Recording data
Observing carefully

Materials and Tools
Atmosphere Investigation Data Work Sheet
GLOBE Cloud Chart
Observing Cloud Type (in the *Appendix*)

Prerequisites
None

How to Observe Cloud Type

From your cloud-type observation site, examine the clouds in the sky. Refer to the GLOBE cloud chart and the definitions found on the *Observing Cloud Type* sheet in the *Appendix* to determine the cloud type(s) present. Check a box on the Atmosphere Data collection sheet for each cloud type that you observe. Do *not* estimate the amount of each cloud type.

Note: In some instances, it may be difficult to distinguish between cloud types (e.g. altocumulus versus cirrocumulus). In these cases, students should use their best judgement and note their uncertainty in the comment section and in their GLOBE Science Notebooks.

Data Submission

Report the following to the GLOBE Student Data Server:

Date and time of the cloud-type observation in Universal Time (UT).
Cloud type(s) observed (you can report more than one cloud type).

Universal Time

A simple way of thinking about Universal Time (UT) is to ask "What time (on a 24 hour clock) is it now in Greenwich, England?" Since Greenwich is on the line of zero longitude, this is a starting point for the global day. At midnight in Greenwich, the UT is 0:00. In recent history, UT was called GMT for Greenwich Mean Time.

Cloud Cover Protocol

Purpose
To observe cloud cover at the school Atmosphere Study Site

Overview
Cloud type is useful in climate studies and is related to precipitation and air temperature.

Time
5 minutes

Level
All

Frequency
Daily within one hour of local solar noon

Key Concepts
Cloud formation
Composition of the atmosphere
Cooling/warming effect of clouds

Skills
Estimating cloud cover
Recording data
Observing carefully

Materials and Tools
Atmosphere Investigation Data Work Sheet

Prerequisites
None

How to Observe Cloud Cover

Take the cloud cover measurements at the same site and time as the cloud-type measurement. Cloud cover should be reported according to the following cloud-cover classification definitions:

Clear
The sky is cloudless or clouds cover less than one-tenth of the sky. (Since a clear sky can include some clouds, it is possible to report cloud type even when you report a clear sky.)

Scattered Clouds
Clouds cover one-tenth through five-tenths of the sky.

Broken clouds
Clouds cover greater than five-tenths through nine-tenths of the sky.

Overcast
Clouds cover more than nine-tenths of the sky.

Note: Even experienced observers can have difficulty accurately differentiating between scattered clouds and broken clouds. If you see more blue sky than clouds, then the cloud cover is considered to be scattered. If you see more clouds than you do blue sky, then the cloud cover is broken.

Data Submission

Record on the Atmosphere Investigation Data Work Sheet one of the four categories of cloud cover each day, and report your findings to the GLOBE Student Data Server.

Rainfall Protocol

Purpose
To measure rainfall at the Atmosphere Study Site

Overview
Climate studies and Earth systems studies require accurate, long-term rainfall measurements.

Time
5 minutes

Level
All

Frequency
Daily within one hour of local solar noon

Key Concepts
- Condensation
- Effects of wind on precipitation measurement
- Meniscus reading

Skills
- *Using* a rain gauge
- *Recording* data
- *Reading* a scale

Materials and Tools
- Rain gauge
- Atmosphere Investigation Data Work Sheet
- Pens or pencils
- Carpenter's level
- Wood post (typically about 10 cm x 10 cm)
- Screwdriver
- Posthole digger

Preparation
Placement of the rain gauge

Prerequisites
None

Background
Rainfall is defined as the depth of water that crosses a horizontal surface over a given time period. You can determine the rainfall by reading the value in millimeters on the measuring scale that corresponds to the water level. Note that this is an expanded scale (i.e., if you hold a ruler up to the scale on the center tube, the distance between the markings on the center tube are not the same as on the ruler). This is because the collection area of the gauge funnel is 10 times the cross-section area of the center tube. This requires that the markings on the inner tube appear larger so the amount of rain can be read directly from the markings.

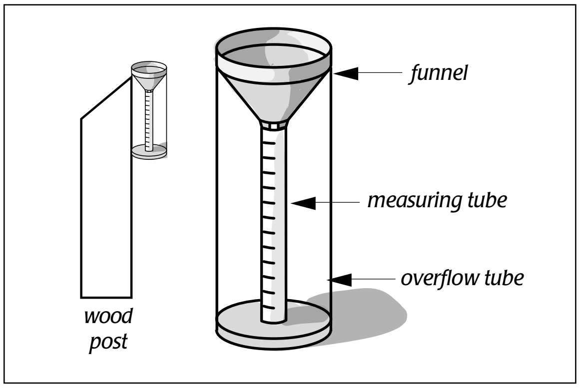
How to Place the Rain Gauge
Students will use a standard rain gauge consisting of four parts. See the Figure ATM-P-2.

1. The funnel, which is attached to the measuring tube;
2. The measuring tube, which is a small cylindrical tube having a uniform diameter and a graduated scale located on the side of the tube;
3. The overflow tube, which is a large cylindrical tube designed to catch any overflow of rain during periods of heavy rainfall; and
4. A mounting bracket.

Insert the measuring tube into the overflow tube and then insert the funnel into the measuring tube and the overflow tube.

Fasten the mounting bracket to a wood post having a width approximately that of the rain gauge. Fasten the bracket so that the top of the rain gauge extends 10 cm above the top of the

Figure ATM-P-2



wood post. If possible, cut the top of the post at a 45° angle to lessen the chance that rain will splash into the rain gauge.

The mounted and placed rain gauge should be level. This can be checked by placing a carpenter's level across the top of the funnel in two directions, one crossing the other at right angles.

How to Measure Rainfall

1. Once the rain gauge is located properly, it must be read daily within one hour of local solar noon.
2. When students read the measuring scale, make sure their eyes are level with the water in the measuring tube and that they read the bottom of the meniscus.
3. After each measurement, they should empty the water from the measuring tube into the clean beaker or jar for the pH measurement by inverting the tube and allowing it to drain. Then they should reassemble and remount the rain gauge. Record the date of the measurement, the UT time of the reading, the depth of rainfall in millimeters, and the number of days rain has accumulated on the Atmosphere Investigation Data Work Sheet.

During periods of heavy rainfall, the rain water may exceed the capacity of the measuring tube and flow into the overflow tube. In this case, the level in the measuring tube should be noted and the tube emptied. Then the water in the overflow tube should be measured by pouring the water from the overflow tube into the measuring tube and noting the water level. This may have to be done several times in order to empty the overflow tube. The resulting depths should then be summed to determine the overall depth.

Even if it has not rained, students should check the rain gauge daily to make sure that it is free of debris (windblown leaves, twigs, papers, etc.). Clean the rain gauge after each reading, rinsing it with distilled water.

Bring the rain gauge indoors when the temperature falls below freezing to prevent the plastic gauge from cracking. The overflow tube can be left outside during periods when the daily temperature ranges from above to below 0 °C and both rain and snow are possible.

Data Submission

Report the following information to the GLOBE Student Data Server:

- Date and time of day of the data collection (in Universal Time)
- Amount of daily rainfall (in millimeters)
- Number of days rain has accumulated

For days when there is no rain, place a zero in the *rain water in rain gauge* column. On days when water in the rain gauge is accidentally spilled or the measurement is lost for some reason, enter the letter "M" (for missing) for the daily rain amount. It is important that a missing value is recorded rather than a zero. (It is a common mistake to substitute zeroes for missing values. This leads to erroneous analyses.)

On days when there is rainfall but the amount is less than 0.5 mm, enter the letter "T" (for trace) for the daily rain amount. This tells us that extremely light rainfall occurred. For some research it is important to know only that it rained and not the amount.

It is important to take daily readings of rainfall. In these cases, report 1 for the number of days rain has accumulated. If it is not possible to read the gauge for several days, you must report the number of days since the gauge was last read or emptied. You must report the number of days even if the reading is zero. Thus, for example, if you emptied the rain gauge on Friday, missed reading the rain gauge on Saturday and Sunday, but read it on Monday, enter 3 days for Monday along with the actual reading.

Solid Precipitation Protocol

Purpose
To measure solid precipitation at the Atmosphere Study Site

Overview
Climate studies and Earth System studies require accurate, long term solid precipitation measurements.

Time
5 minutes

Level
All

Frequency
Daily within one hour of local solar noon.

Key Concepts
Change of state
Heat capacity
Density of snow

Skills
Reading a scale
Recording data

Materials and Tools
Meter stick (If your snow tends to be deeper than one meter, you will need a longer measuring pole.)
Snowboard

Prerequisites
None

Background
A snowboard is a thin, flat surface that rests on top of earlier layers of snow. New snow falls on top of it and can be measured with the measuring stick. The board may be made of thin plywood (1 cm or 3/8"). The board should be at least 40 cm by 40 cm in size so that more than one snow-depth measurement can be made. Mark the location of the snowboard so that it can be easily located after it has been covered by a new snowfall.

In most cases a meter stick will be adequate to use as the "measuring pole". However, in regions where the 24 hour snowfall and/or snow accumulated on the ground throughout the winter exceeds 1 meter, a longer measuring stick will be necessary. In these cases, a measuring pole can be made by taking a straight piece of wood and carefully marking off lengths using a ruler and a permanent marker. The pole may be permanently installed as it is often difficult to push a pole vertically through more than 1 meter of snow.

How to Measure Solid Precipitation
1. For your first snowfall, insert the measuring stick vertically into the snow until it rests on the ground's surface. *Be careful not to mistake an ice layer or crusted snow for the ground.* Repeat the measurement in several places where the snow is least affected by drifting. If there is no new snow, enter 0. If the measured depth is between 0 and 0.5 millimeter, enter the letter "T" (for trace).
2. Place the snowboard on top of existing snow and push gently into the snow so that its surface is flush with the snow's surface. Place a flag or other marker nearby to help you locate the snowboard after the next snowfall.
3. After a new snow has fallen on earlier snow, gently insert the measuring stick into the snow until it touches the snowboard. Take several measurements at different spots on the snowboard and average these measurements. This will be

your depth of new snow on the snowboard.

4. Measure total depth of snow on the ground at the same time as the daily accumulation. The procedure is the same as for measuring the first snowfall: insert the measuring stick vertically into the snow in several places (not in the area of the snowboard) and take the average of the depth readings.

Determining Liquid-Water Content of Daily Solid Precipitation

Not all snowfalls are alike. Some are light and fluffy while others are wet and heavy. The daily liquid equivalent of solid precipitation is determined by melting a sample of snow and measuring the volume of the water.

For this measurement, a collection container is necessary. When outside temperatures are below freezing, the plastic rain gauges used for liquid precipitation measurements may crack and break, so they should be brought indoors. However, the large, overflow cylinder of the rain gauge makes an ideal container to collect snow to determine liquid-water content.

1. Once you have measured the depth of daily snowfall on the snowboard, take the large cylinder from the rain gauge and invert it on the snowboard, pushing the cylinder down carefully so that it touches the board's surface. If the depth of snow is greater than the depth of the overflow cylinder, you may compact the snow in the cylinder. In doing this, be careful that you are not pushing snow out of the path of the cylinder. If the snow is too deep, you may not be able to compact the snow into the cylinder as a single sample. Depending on the size of your snowboard and the depth of snowfall, there are at least two ways to get that circle of snow into your cylinder.

Method A

If your snowboard is not large or heavy, hold the cylinder against the board and invert both snowboard and the cylinder. This will cause the snow outside the cylinder to fall off the board, so be sure you've made your depth measurement first. The snow trapped in the cylinder can now be taken indoors.

Method B

If your snowboard is too big or heavy to turn over easily or if the snow column, even when compacted, will not fit into the cylinder, you will have to transfer the snow into the cylinder or other container by hand. Carefully lift the cylinder off of the board and you should have a nice circle of snow in the shape of the cylinder. Carefully scoop the snow from within this circle into your cylinder or other container.

2. Once the snow is inside the cylinder or other container, bring it indoors and allow it to melt. Place a cover over the container to prevent evaporation.
3. When the snow has melted, carefully pour the water into the measuring tube of the rain gauge and read the depth of water in the same way you read the rainfall.

It is possible that an overnight snowfall may melt before the daily precipitation measurement is made. If you have left your overflow cylinder outside, you can still report the liquid water equivalent of your snowfall. Enter "M" for Daily depth of new snow and 0.0 mm for Total depth of snow on the ground. In cases like these a message can be entered under comments noting that snow fell and melted or blew away. If you have measured the depth of snow before it melted, this could also be reported under comments, along with the time you made the measurement. Remember that measurements reported in the regular section of the data sheet should be the measurements taken within one hour of local solar noon.

Setting Up for the Next Measurement

After you have completed your snow observation, clean the snowboard and again place it flush on the snow's surface

Data Submission

Report the following information to the GLOBE Student Data Server:

- Date and time of data collection (in Universal Time)
- Total depth of snow on the ground (mm)
- Daily depth of new snow (mm)
- Number of days snow has accumulated on the snowboard
- The depth of water from the melted snow on the snowboard (mm).

Note: If snow has fallen but, for some reason, measurements cannot be taken (for example, the snowboard has blown away or someone accidentally cleared it before a measurement could be taken) then enter the letter "M" (for missing). The total snow depth can still be reported.

On days when the snowfall is so small that a depth cannot be read, enter the letter "T" (for "trace") for the daily snowfall.

It is important to take daily readings of snowfall, but if this is not possible, then, if the snowfall has not been measured for several days (for example over the weekend), enter the number of days since the snowboard was last cleared along with the amount of snowfall. This indicates that the measured amount was collected over more than a 24-hour period. Thus, for example, if you missed reading the snowboard on Saturday and Sunday but read it on Monday, you would enter 3 days for Monday along with the actual reading.

Precipitation pH Protocol

Purpose
To measure pH of rain and snow

Overview
The pH of precipitation affects the region on which it falls. *Acidic precipitation* can affect vegetation, buildings, statues, and change the pH of water in surface water bodies or in the soil.

Time
5 minutes for actual measurements
5 minutes to calibrate the pH pen or pH meter

Level
All

Frequency
For rainfall: Whenever you have accumulated at least 2 mm of rainfall in your rain gauge

For snowfall: Whenever there has been enough new snowfall such that you can collect snow which has not been in DIRECT contact with the ground or with your snowboard and this snow, when melted, produces at least 20 ml of liquid.

Key Concepts
Factors affecting the pH of precipitation

Skills
Using pH measuring equipment
Recording data

Materials and Tools
pH measuring equipment (pH indicator paper for beginning; pH pen for intermediate; pH meter for advanced level students; plus necessary calibration materials)
Rain gauge
Snowboard
100 mL beaker

Preparation
Read and be familiar with *Hydrology Investigation pH Protocol*. If your students are at the intermediate or advanced level, make sure your pH pen or pH meter has been conditioned and calibrated according to the instructions in that protocol.

Prerequisites
None. Although the equipment used in this protocol is the same as that in *Hydrology Investigation pH Protocol*, you do not need to be making pH measurements at a water sample site in order to make precipitation pH measurements.

Beginning Students: pH Indicator Paper
It is quickest and easiest to take a clean, dry beaker and pH paper with you to your rain gauge site and make the pH measurement immediately after reading and recording the rainfall amount.

1. Use a clean, dry 100 mL beaker.
2. After reading and recording the amount of rainfall in your rain gauge, if there has been at least 2 mm of accumulated rainfall, pour the rain water into the beaker. If there has been a large amount of rainfall, you need only fill the beaker about half full with the rain water.
3. Dip one strip of pH indicator paper into the rain water in the beaker and hold it there for about 20 seconds. Make sure all of the colored segments of the paper are immersed in the rain water.

4. Remove the paper from the water and compare the resultant color segments with the chart on the pH indicator paper box. Try to find a sequence where all color segments on the paper match all segments on one of the stripes on the box.
5. If the reading is unclear, the paper may need more time to fully react. Place the paper back in the rain water in the beaker for an additional 20 seconds, then repeat steps 4 and 5. Repeat until you are satisfied that the reading is accurate. If, after 2 minutes, the reading is still unclear, start all over with a new strip of paper. If the test fails a second time, indicate this on your Atmospheric Investigation Data Work Sheet.
6. If you are satisfied that you have a good pH reading, record the pH value on the Atmosphere Investigation Data Work Sheet.
7. If you have had enough rainfall, repeat Steps 2 through 5 as a quality control check.
8. Report your measured pH to the GLOBE Student Data Server
9. Regardless of whether or not it has rained, your rain gauge must be thoroughly scrubbed using distilled water and dried at least once per week. Any foreign material in your rain gauge can affect your pH reading. DO NOT USE SOAP OR DETERGENTS IN YOUR RAIN GAUGE AS RESIDUES CAN AFFECT YOUR pH READING!

Intermediate/Advanced: pH pen/ pH meter

Step 1: Conditioning and calibration of the pH pen or meter

Follow the instructions in *Hydrology Investigation pH Protocol* for conditioning and calibration of your instrument.

Step 2: Measuring the pH of the collected rainfall

Take your calibrated pH pen or meter and a clean, dry beaker with you to your rain gauge site, and make your pH reading immediately after reading the rainfall amount.

1. Prior to leaving the classroom, remove the cap and rinse the electrode and the surrounding area of your pH pen or meter with distilled water. Blot the area dry with a soft tissue.
2. Obtain a clean, dry 100 mL or larger beaker, and take it, as well as your pH pen or meter, with you to the rain gauge site.
3. At the rain gauge, read and record the amount of rainfall.
4. If there is at least 2 mm of rainfall in your gauge, pour the rain water into the beaker. If there has been a large amount of rainfall, you need only fill the beaker about half full with rain water.
5. Immerse the electrode of your pH pen or meter in the water in the beaker. Be sure that the entire electrode is immersed but avoid immersing it any further than necessary. If you do not have enough rain water to completely immerse the electrode, do not make a rainfall pH measurement.
6. Stir the rain water once with the pH pen or meter and then let the display value stabilize.
7. Once the display value is stable, read the pH value and record it on the Atmosphere Investigation Data Work Sheet.
8. If you have enough rainfall left in your gauge, repeat steps 4 through 7 for another sample as a quality control check. The two pH values should agree to within

0.2 (which is the accuracy of this technique). If they do not, make a third measurement with a new sample of rain water (if there is sufficient water in the gauge). If there is not sufficient rain water for a third measurement, do not report a precipitation pH value to the GLOBE Student Data Server, and recheck the calibration of your pen or meter before your next measurement.

9. If you only have enough rain water to make a single pH measurement, report this pH value to the GLOBE Data Server.
10. If there is enough rain water for two separate measurements to be made, and these measurements agree to within 0.2, report the average pH value to the GLOBE Data Server.
11. If you had enough rain water to make three or more pH measurements, take the average of the pH values measured. If all recorded values are within 0.2 of this average, report the average value to the Student Data Server. If there is only one outlier (a value that is far different from the rest), discard that value and calculate the average of the other values. If they are all now within 0.2 of this new average, report this new average to the Data Server, with the notation that 3 or more measurements were made (even if all three measurements were not included in the average pH value reported). If there is a wide scatter in pH readings, do not report a value to the Data Server. Check the calibration of your instrument and discuss procedure and potential sources of error.
12. Rinse the pH pen or meter with distilled water, blot it dry with soft tissue, replace the cap on the probe, and turn off the instrument.
13. Regardless of whether or not it has rained, your rain gauge must be thoroughly scrubbed using distilled water and completely dried at least once per week.

    Any foreign material in your rain gauge can affect your pH reading. DO NOT USE SOAP OR DETERGENTS IN YOUR RAIN GAUGE AS RESIDUES CAN AFFECT YOUR pH READING!

Collection of Snow for pH Measurement

Although you may be measuring the depth of snowfall and its liquid water equivalent, you need to be a bit more careful in collecting snow to make your pH measurement. The snowboard that you use for snow depth (see *Solid Precipitation Protocol*) may sit out for quite a while before there is actually any snow on it. Thus, material like leaves or soil may collect on the board. When you take a "core" of snow from the snowboard to determine liquid water equivalent, the snow at the bottom (that is in direct contact with the board) may have reacted with the material on the board (or the board itself). What we really want to measure is the pH of the snow itself. Therefore, if you are going to measure snow pH, you will need to gather a second sample of snow in addition to the sample gathered to determine liquid water equivalent.

For the pH snow sample, you want to also take a *core* of snow from the snowboard. However, you don't want to go all the way down to the board itself if you can help it. The reason you want to take a core rather than just scooping snow off the top is because the pH of the snow may change the longer the snow falls. What we want to get is the average pH of the snowfall. Thus, we want a core of snow, but stopping just short of getting all the way down to the snowboard itself. In order to obtain enough snow to produce at least 20 mL of water once the snow melts, you may collect several cores from other locations on your snowboard.

Any clean, dry, deep container (glass or plastic) can be used to collect the snow sample for the pH measurement. Once you have collected the snow, take the container inside and cover it. Let the snow melt at room temperature.

When the snow has melted you are ready to make your pH measurement as described in the sections above using the melted snow instead of the rain water and taking the measurement in the classroom instead of at the Atmosphere Study Site.

Maximum, Minimum, and Current Temperatures Protocol

Purpose
To measure air temperature at the Atmosphere Study Site

Overview
Climate studies and Earth systems studies require accurate, long-term air temperature measurements.

Time
5 minutes

Level
All

Frequency
Daily within one hour of local solar noon

Key Concepts
Heat
Temperature
Convection
Conduction
Radiation

Skills
Using a thermometer
Recording data
Reading a scale

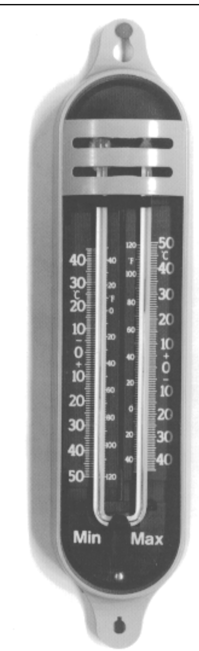
Materials and Tools
One maximum/minimum thermometer
An instrument shelter
A second thermometer for calibrating the maximum/minimum thermometer
Atmosphere Investigation Data Work Sheet

Prerequisites
None

Background

The maximum/minimum thermometer is a U-shaped tube with two indices that indicate the maximum and minimum temperatures. See Figure ATM-P-3. On the maximum side, the temperature scale is such that temperature increases as you go from bottom to top (as with household thermometers). On the minimum side, the scale shows temperature decreasing as you go from bottom to top. Thus, as the temperature increases, the indicator at the top of the mercury column on the maximum side of the thermometer is pushed upward. When the temperature drops, the indicator remains in place to indicate the maximum temperature. Similarly, as the temperature decreases, the indicator above the mercury column on the minimum side is pushed upward. When the temperature again increases, this indicator remains in place to indicate the minimum temperature.

Figure ATM-P-3: Maximum/Minimum Thermometer



Note: The mercury pushes the bottom of indicators until the maximum or minimum temperature is reached. Therefore, students read the maximum and minimum at the bottoms of the indicators.

If your thermometer has a Fahrenheit scale, paint over it so that students will not read it by mistake. Note that the thermometer shown in Figure AT M-P-3 has a Fahrenheit scale which should be painted black.

Before using your maximum/minimum thermometer, make sure that the column of mercury is continuous because it sometimes separates into segments during shipping. If there are gaps in the mercury column, grasp the thermometer by the case, making sure the thermometer is in an upright position, and shake the case until the mercury forms a continuous column. Do not press against the stem of the thermometer as this could cause breakage. You may need to tap the bottom of the thermometer against the palm of your hand as well.

Calibration

Your maximum/minimum thermometer should be calibrated upon installation and again every six months after installation. (More frequent calibration may be required if you find the current temperature does not read the same on both scales or, if at some point, the mercury column becomes discontinuous and needs to be fixed. See above.)

To calibrate the maximum/minimum thermometer, you should compare it with a calibration thermometer. The calibration thermometer will be a typical, liquid-filled, single-tube thermometer that can record temperatures at least as low as -5 °C. The calibration thermometer itself must first be tested for accuracy by placing it in an ice-water bath.

1. Prepare a mixture of one part liquid water to one part crushed ice.
2. Allow the ice-water bath to sit for 10 to 15 minutes so it reaches its lowest temperature.
3. The bulb of your calibration thermometer should then be placed in the bath. Gently move the thermometer around in the ice-water bath so that it will be thoroughly cooled. The thermometer should read between 0.0 and 0.5 °C. If it does not, use another thermometer.
4. Once you are confident of the accuracy of your calibration thermometer, hang it by a hook in the instrument shelter. See instructions below for placing the maximum/minimum thermometer.
5. After 24 hours, compare the temperatures on both thermometers. If they differ, the maximum/minimum thermometer should be calibrated to the temperature of the calibration thermometer. Adjust the temperature scales on both sides of the thermometer by loosening the small screw located in the back of the thermometer. Once this screw is loosened, the scales can slide up or down independently of each other.

Placing the Maximum/Minimum Thermometer

Mount the maximum/minimum thermometer in the instrument shelter so that there is air flow all around the thermometer case. The thermometer should be attached to blocks on the rear wall of the shelter so that no part of it touches the walls, floor, or ceiling of the shelter. The thermometer must be 1.5 meters above the ground or 0.6 meters above the average maximum snow depth, whichever is higher. The shelter protects the thermometer from radiation from the sun, sky, ground, and surrounding objects, but allows air to flow through so the air temperature inside the shelter is the same as the air temperature outside the shelter.

The instrument shelter should be mounted on a post that is secured in the ground as firmly as possible so as to eliminate vibrations caused by strong winds. Vibrations can displace the indicators on the maximum/minimum thermometer and thus cause erroneous readings. The shelter's door should face north in the Northern Hemisphere and south in the Southern Hemisphere to reduce exposure of the thermometer to direct sunlight when the door is open for the daily measurement.

The instrument shelter should conform to the specifications given in the *GLOBE Instrument List* in the *Toolkit* section of this guide. It may be constructed using the plan in the Toolkit. It should be painted white both inside and outside. The lock is to prevent tampering with the instruments. Mounting blocks should be installed on the interior to ensure that the maximum/minimum thermometer does not touch the back wall. The door is hinged on the right side (this is not shown in the diagram. The parts should be screwed together. The plans are specified in metric units. See the Toolkit for detailed shelter construction plans.

Once the shelter is in use, occasionally dust its inside with a dry cloth.

How to Measure Air Temperature

1. Assign a team of students to read the thermometer daily within one hour of local solar noon. They should stand as far from the thermometers as possible to prevent body heat from changing the temperature reading. This is very important in cold weather. Do not touch or breathe on the temperature-sensing parts of the thermometer as this, too, may affect the reading.
2. Students should read the current daily temperature at the top of the column of mercury on either the maximum or minimum sides of the u-tube thermometer. Make sure that their eyes are level with the top of the mercury column. Otherwise the reading will be too high or too low.
3. Take the maximum and minimum readings at the base of the indicators. Make sure the eyes of the observer are level with the base of the indicator.
4. Once the maximum, minimum, and current temperatures are read, students should reset the indicators. This is done by using a small magnet to drag the indicators down until they are on top of the mercury column. To avoid losing the magnet, attach it either to the shelter or to the thermometer with a piece of string.

When a temperature observation is missed, reset the thermometer at the next observation and record only the current temperature at that time. Since more than 24 hours have elapsed between readings, we have no way of knowing on which day the maximum and minimum temperatures occurred.

Data Submission

Report the following data to the GLOBE Student Data Server:

- Date and time of the data collection in Universal Time
- Current air temperature
- Maximum daily air temperature
- Minimum daily air temperature

Learning Activities

Observing, Describing, and Identifying Clouds

Students will begin to learn cloud types and their names.

Estimating Cloud Cover: A Simulation

Students will practice estimating how much of the sky is covered by clouds.

Studying the Instrument Shelter

Working in teams, students will explore how the placement of the instrument shelter and its characteristics can influence measurements.

Building a Thermometer

Students will construct simple thermometers to understand how and why liquid-in-glass thermometers work.

Land, Water, and Air

This hands-on activity will show students the different cooling and heating rates between land and water, which accounts for much weather

Cloud Watch

Students will monitor clouds and weather to begin to understand the connections between the two.

Observing, Describing, and Identifying Clouds

Purpose

To enable students to observe clouds, describe them in a common vocabulary, and compare their descriptions with the official cloud names

Overview

Students observe and sketch clouds, describing their forms. They will initially generate descriptions of a personal nature and then move toward building a more scientific vocabulary. They correlate their descriptions with the standard classifications using the ten cloud types identified for GLOBE. Each student develops a personal cloud booklet to be used in conjunction with the GLOBE Cloud Chart.

Time

Two class periods. May be repeated on days when different kinds of clouds are present

Level

All

Key Concepts

Clouds are identified by their shape, altitude, and precipitation characteristics.

Skills

Observing and *describing* the appearance of clouds

Identifying the ten major cloud types

Estimating cloud height

Recording and *organizing* cloud data in the GLOBE Science Notebook

Materials and Tools

GLOBE Cloud Chart

Observing Cloud Type Sheets (in the Appendix)

GLOBE Science Notebooks

Reference books containing cloud images

Still or video camera to photograph clouds (optional)

Preparation

Obtain cloud reference books and mark the appropriate pages.

Prerequisites

None

Background

Accurate weather forecasting starts with careful and consistent observations. The human eye represents one of the best (and cheapest) weather instruments. Much of what we know about the weather is a result of direct human observation conducted over thousands of years. Although being able to identify clouds is useful in itself, observing clouds on a regular basis and keeping track of the weather associated with certain kinds of clouds will show students the connection between cloud types and weather. Recognizing cloud types can help you predict the kind of weather to expect in the near future. We do not describe those connections here, but there are numerous weather books that can help you and your students make them. Inviting a local meteorologist to visit your class and talk with the students is a sure way to stimulate interest in the relationship between clouds and weather patterns.

In this activity, we ask students to look carefully at clouds, sketch them, and describe them in their own words *before* using the official names. The activity can be repeated on different days when different kinds of clouds are present. In fact, if you can be spontaneous, it would be nice to take a break and do some outdoor "cloud work" whenever a new kind of cloud appears in the sky. Over time, students can build up a considerable familiarity with cloud types. And, if you cannot always take the students outside when some interesting clouds appear, perhaps you can observe through a window.

Students Develop a Personal Cloud Booklet

Students should develop, either in their GLOBE Science Notebooks or in separate cloud booklets, an individual, personal set of notes on clouds and cloud types. They should devote one page of their GLOBE Science Notebooks to each individual cloud type they identify. They can include not only their own observations and descriptions but also photographs of clouds that they take or that they clip from other sources. On any given day students may observe several kinds of clouds in the sky at the same time. If several types of clouds are present, they should record each of the types on a separate page of their GLOBE Science Notebooks.

Identifying and Classifying Clouds

The GLOBE protocol asks you to identify ten common types of clouds. The names used for the clouds are based on **three factors:** their **shape**, the **altitude** at which they occur, and whether they are **producing precipitation.**

1. Clouds come in three basic shapes:
   cumulus clouds (heaped and puffy)
   stratus clouds (layered)
   cirrus clouds (wispy)
2. Clouds occur in three altitude ranges (specifically, the altitude of the cloud base):
   High clouds (above 6,000 m), designated by "cirrus or cirro-"
   - Cirrus
   - Cirrocumulus
   - Cirrostratus

   Middle clouds (2,000 - 6,000 m), designated by "alto-"
   - Altocumulus
   - Altostratus

   Low clouds (below 2,000 m), no prefix
   - Stratus
   - Nimbostratus
   - Cumulus
   - Stratocumulus
   - Cumulonimbus

Note: While both cumulus and cumulonimbus clouds may have their bases starting below 2,000 m, they often grow thick enough to extend into the middle or even high range. Thus, they are often referred to as "clouds of vertical development." Only high clouds are wispy and so the term cirrus has become synonymous with wispy as well as referring to high clouds.

3. Clouds whose names incorporate the word "nimbus" or the prefix "nimbo-" are clouds from which **precipitation** is falling.

Cloud Identification Tips

Several things are useful to know in identifying and naming clouds according to the official classifications:

Clouds that are wispy and high in the sky are always cirrus of one type or another. If the cirrus clouds contain waves or puffs, then they are cirrocumulus. If they form continuous layers that seem to cover the sky high up, they are cirrostratus.

Clouds at middle altitudes are designated by the prefix "alto-." If in layers, they are altostratus; if in heaps and puffy, they are altocumulus.

Clouds that form at low altitudes (below 2,000 m) are either of the cumulus or stratus family. Clouds in the cumulus family are puffy and heaped. Clouds in the stratus family form in layers or sheets that cover broad expanses of sky.

Low clouds that are dark, threatening and *actually producing rain* receive the designation "nimbus." Nimbostratus clouds cover the entire sky with broad sheets and produce steady rain. Nimbostratus clouds are larger horizontally than vertically. The rainfall associated with nimbostratus typically is low to moderate in intensity, but falls over a large area for an extended period of time. Cumulonimbus have dark bases and puffy tops, often anvil-shaped, and are sometimes called "thunderheads." They tend to produce heavy precipitation, typically accompanied by lightning and thunder.

Using Photography

It should not be hard to find photographs of clouds in books, charts, and magazines. However, the students will enjoy taking their own photographs of clouds. Introduce this as an activity after they have sketched and described clouds in their own words. Video photography of clouds in motion also presents a new perspective on cloud formation and behavior, particularly if you can use a tripod and time-lapse photography.

Part 1: Describing Clouds In Your Own Words

What To Do and How To Do It

1. Organize the students into two-person teams. Send them outside with their GLOBE Science Notebooks to an open location to observe the clouds. Each student should draw a detailed sketch of the clouds in the sky. If there are several different kinds of clouds present, then they should sketch each specific kind on a separate page of their notebooks.
2. Each student should record the date and time of day and describe the appearance of the clouds next to the sketch. They should use as many words as necessary to describe the appearance of the clouds. Emphasize that there are no right or wrong answers and that they should use whatever words seem appropriate to them. Some possible student responses:

   Size: small, large, heavy, light, dense, thick

   Shape: fluffy, stringy, cottony, lumpy, torn, smooth, patchy, sheets, ragged, looks like a...

   Color: gray, black, white, silvery, milky

   Description: thunderclouds, menacing, threatening, gloomy, enveloping, beautiful, streaked, foggy, bubbly, scattered, moving, swirling
3. Upon returning to the class, pairs should join together to share descriptions. Ask each group of four to compile a "group list" of all the words they used to describe each cloud type they observed. They should select the words they think are the best ones for describing the clouds they saw.
4. Using the GLOBE Cloud Chart, they should match their sketches with one of the photographs and record the scientific name of the cloud type next to their sketch.

Part 2: Comparing Your Descriptions to the Official Descriptions

What To Do and How To Do It

1. (You may choose to postpone this discussion until the class has accumulated descriptions of several different kinds of clouds.)

   Initiate a class discussion. Ask one four-person group to draw its cloud sketch on the board and record the words their group used to describe the cloud. If several different clouds have been observed, have a different group do each type. Ask other groups to contribute additional words they used to describe these clouds.

   Ask the students to group the words they used into clusters that seem to go together. Ask them to name the specific features of the clouds (such as size, shape, color, altitude, or other features) to which these clusters refer. Do these clusters represent the main cloud features to which they think an observer should pay attention? Are there any cloud features that have not been included? What would they say is the basis of their system, that is, what features of clouds does it pay attention to?
2. Ask the students to indicate the "official" names for the clouds pictured on the board. Explain that the official system used to classify clouds relies upon three features of clouds: shape, altitude, and precipitation. Compare the official system to the classification system they developed on their own. What cloud features does each include and omit?

Ask students which of their words they would use to describe each of these cloud families:

- stratus clouds
- cumulus clouds
- cirrus clouds
- nimbus clouds

3. Repeat the observation, sketching, and description of different cloud types on subsequent days as new clouds appear in your sky. Have students develop a separate page of their GLOBE Science Notebooks for each new cloud type they observe. Have them record both the official name of the cloud and their own preferred descriptions of it. Continue to discuss the basis for the official classification system.

Adaptations for Younger and Older Students

Younger students can describe clouds in terms of their basic family type: cirrus, cumulus, and stratus. They can also describe the height of the clouds: low, medium, or high; their shape: large or small; and their color: white, gray, or black.

Older students can correlate cloud types with the appearance of certain types of weather. See the *Cloud Watch Learning Activity*. Students also can pay attention to the sequence of cloud types over the course of several days and can investigate the factors that cause clouds to form.

This activity can present interesting possibilities for collaboration with an art teacher or a literature teacher, each of whom can contribute a different, perhaps nonscientific, perspective on the description of clouds.

Further Investigations

Examine the correlation between wind and clouds. Chart the wind direction and speed for each observable cloud type.

Explain the connection between the hydrologic cycle and atmospheric conditions.

Satellite and shuttle photos allow observations of the dynamics of our atmosphere and the examination of large-scale phenomena that are not possible from land. Use space-based imagery to predict weather or to track storms. Consider the merits and disadvantages of space images versus local meteorological information and data.

Track storms and clouds from a distance to aid in understanding local weather conditions. Use binoculars to study clouds and their formations from a distance. Use local maps to help identify the distance of landmarks and the speed at which clouds are moving.

Create cloud games to practice identification skills and concepts:

Cloud Game #1: Have each student create a set of 3" x 5" index cards that includes names of the ten cloud types. A second set of cards includes illustrations of each of the ten types. Pairs of students combine cards, turning them face down. Partners alternate turning over two cards at a time, attempting to locate a match. A successful match results in another turn. Play continues until all cards have been matched. The winner is the partner with the most matched pairs.

Cloud Game #2: Groups of students can generate questions about clouds: appearance, shape, altitude, and percentage of dominant cover. On a 3" x 5" index card write the statement as an answer. For example: "Scattered Clouds" is the answer to the question, "What is the cloud cover when between a tenth and a half of the sky is covered with clouds?" Divide the class into teams to play. Players respond to the answer cards in the form of a question (see above).

Estimating Cloud Cover: A Simulation

Purpose

To enable students to understand the difficulties of visually estimating the percentage of cloud cover, to practice estimating cloud cover using paper simulations, and to evaluate the accuracy of their estimates

Overview

Working in pairs or small groups, students will use construction paper to simulate cloud cover. They will estimate the percentage of cloud cover and assign a cloud cover classification.

Time

One class period

Level

Intermediate and Advanced

Key Concepts

Using a simulation to explore the accuracy of observations

Skills

Estimating simulated cloud cover
Communicating mathematically
Collecting and *recording* data
Organizing data in tables

Materials and Tools

GLOBE Science Notebooks
Sheets of colored construction paper, one blue and one white per student
Glue stick or tape

Prerequisites

Familiarity with the cloud cover classification system

Familiarity with fractions and percentages

Background

Even experienced observers have difficulty estimating cloud cover. This seems to derive, in part, from our tendency to underestimate the open space between objects in comparison to the space occupied by the objects themselves, in this case the clouds. Students have an opportunity to experience this perceptual bias themselves, to reflect on its consequences for their scientific work, and to devise strategies to improve their ability to estimate cloud cover.

What To Do and How To Do It

Review the cloud-cover protocol with the students. Explain that they will simulate cloud cover using construction paper and try to estimate the amount of cloud cover represented by white scraps of paper. Demonstrate the procedures covered in steps 3 - 6 below so that students understand how to proceed.

1. Provide each student with the necessary materials:
   - one sheet of light blue construction paper
   - one sheet of white construction paper divided into 10 equal segments
   - GLOBE Science Notebooks
   - glue stick or tape.
2. Organize students into pairs.
3. Tell each student pair to choose a percentage of cloud cover that they wish to represent. They must choose a multiple of 10% (i.e. 20%, 30%, 60%, etc. not 5% or 95%). They should not reveal the percentage they have chosen to anyone else.

4. Working separately, each pair should cut their white paper so that it represents the percentage of cloud cover they have chosen. For example, if they have chosen 30%, they should cut out 30% of their white piece of paper and recycle the remaining 70%.
5. Students then tear their white paper into irregular shapes to represent clouds.
6. The students paste or tape the smaller cloud pieces onto the blue paper, thus representing the cloud cover.
7. Students take turns visiting each others' simulations and estimating the percentage of cloud cover. They also classify each simulation as "clear, scattered, broken, or overcast." They record their estimates in their notebooks, using a table similar to that shown in Figure ATM-L-1.

You may choose to have all students visit all the simulations, or divide the class in some way so that students visit only some of the simulations.

8. When students complete their estimates of cloud cover, create a table on the board to compare the estimates with the actual percentages. See Figure ATM-L-2.
9. Create a second table that compares correct classifications with incorrect classifications. See Figure ATM-L-3.
10. Discuss with the class the accuracy of their estimates.
    Which were more accurate—the percentage estimates or the classifications?
    Where did the greatest errors occur?
    Can students come up with a quantitative measure of their collective accuracy?
    Does the class have a tendency to overestimate or underestimate cloud cover?
    What factors influenced the accuracy of the estimates (e.g. size of the clouds, clustering of the clouds in one part of the sky, the percentage of sky that was covered)?
    Do students feel that making these estimates is something one has a knack for, or is it something that can be learned?
    Where else might such spatial estimation skills be valuable?
    Which cloud classifications were the easiest and most difficult to identify?
    What strategies enabled students to succeed?

Figure ATM-L-1

Name	Estimated percent	Classification
Jon & Alice	40%	scattered
Juan & Jose	70%	broken

Figure ATM-L-2

Name	Actual %	Underestimates	Correct estimates	Overestimates
Jon & Alice	50	4	5	12

Figure ATM-L-3

Name	Correct classification	Classified too little cover	Classified correctly	Classified too much cover
Jon & Alice	Scattered	4	9	8

What strategies might produce more accurate classifications?

Adaptations for Younger and Older Students

Younger students may need instruction regarding the identification of fractional *equivalents* and converting simple fractions to percents.

Older students can produce and videotape daily forecasts simulating a local news or weather channel. The broadcast format can include clips of dominant cloud types, percentage of cloud cover and visibility reports.

Studying The Instrument Shelter

Purpose

To discover why the instrument shelter is built the way it is

Overview

Students will explore some of the characteristics of the instrument shelter and its placement. The main part of this activity will be to construct shelters that have varying properties and investigate the effect of these properties on the measured temperature. Students should be asked to predict what they believe will happen for each of the different shelter designs.

Time

One class period for discussion of the shelter and design of an experiment. Two to three additional class periods to experiment with model shelters.

Level

All

Key Concepts

Heat transfer through radiation, conduction, and convection

Skills

Hypothesizing and *predicting*

Designing experiments

Collecting data

Organizing and *analyzing* data

Communicating experimental results orally and in writing

Materials and Tools

At least two cardboard instrument shelters (depending on the number of properties to be explored and the availability of materials). These could be in the form of ready-made boxes such as an oatmeal container or a shoe box.
It is best if all the experimental shelters are the same, so that size and shape do not become factors. If only sheets of cardboard are available, then shelters can be constructed from some agreed-upon plan.

For every property to be explored, at least two cardboard shelters will be needed.

Depending on the number of characteristics to be investigated, the following materials may be needed:

White paint and black paint (to investigate color)

Two paint brushes (if paint is used)

Heavy-duty scissors (necessary if the shelters must be made from sheets of cardboard and also to investigate the purpose of slits in the shelter)

Paper (to compare the effect of having shelters made of different materials)

Two or more thermometers per student group (depending on the number of properties to be tested at the same time)

String

One or more wooden posts, strong enough to be placed in the ground and hold the instrument shelter (shelters can be nailed onto the posts)

Nails (to attach shelters to the posts, if necessary)

Hammer

Meter stick

The actual GLOBE instrument shelter
If the actual shelter is not available, then the students should have the picture and physical description of it given in the *Toolkit*.

Preparation

Gather those materials needed to construct the shelters. Students could bring oatmeal boxes (round) or shoe boxes from home.

Prerequisites

An assembled instrument shelter

Background

While it may seem that air temperature should be an easy enough measurement to make, it is not necessarily easy for many people around the world to make precisely the same measurements so they can be compared with each other. In order to really understand the temperature being measured, we all need to measure the same thing. Factors such as wind, direct sunlight, and moisture can affect a thermometer and so we must protect these instruments by placing them in a shelter that is built to a specific set of characteristics. In addition, where this shelter is placed and how the thermometer is placed inside of it are of critical importance.

We need to be certain that the temperature differences reported from various areas are due to real differences in the air temperature and do not just reflect the fact that one person put a thermometer in a shelter in the middle of a grassy field and someone else put a thermometer on the window in direct sunlight.

What To Do and How To Do It

Day One

1. You should start the discussion by asking students to identify the major characteristics of the GLOBE shelter that could influence the temperature inside it. These would include:
   - The color of the shelter
   - The slits in the shelter
   - The materials of which the shelter is made

   The discussion should turn to why the students think these characteristics are important.
2. The discussion of the physical characteristics of the shelter should be followed by a discussion of the placement of the shelter and the thermometer inside the shelter. Questions to ask are:
   - Why should the shelter be located away from buildings and trees?
   - Why should it be placed over a natural surface, such as grass?
   - Why should it be placed 1.5 meters above the ground?
   - Why should the shelter be oriented with the door facing north in the northern hemisphere and south in the southern hemisphere?
   - Why is the thermometer not supposed to touch the shelter?

Students should predict the effect that each of the above parameters has on the measurement of temperature. Then it will be time to test their predictions.

Day One/Day Two (depending on how long the discussions take)

1. Students should be divided into teams. The number of teams will be determined by the number of properties to be investigated, the availability of materials, and the number of students. Up to eight teams could be formed to explore the eight basic parameters discussed above.
2. Each team should construct two shelters. This is a simple task if students use ready-made boxes such as oatmeal or shoe boxes, but will be more complicated if they must make shelters from sheets of cardboard.

   If shelters are made from sheets of cardboard, the actual design of the shelter (whether it is a cylinder, like an oatmeal box, or a rectangle, like a shoe box) is not as important as the fact that all shelters should be as close to the same design and size as possible.
3. Each team chooses or is assigned a property to explore. For those investigating the physical properties of the shelter, further work on the shelter will be necessary. The following are possible alterations to shelters to study the properties:
   - Paint one shelter white and one black
   - Make one shelter with slits and one without (paint both white)
   - If you are using ready-made boxes, then use white paper to construct a shelter of similar shape and size to the cardboard one. Paint the cardboard shelter white.

4. All shelters should be mounted on posts (unless a team is investigating the effect of the height of the shelter above the ground). For most teams, the posts do not need to be more that a meter high. The team investigating shelter height above the ground should leave one shelter unmounted and mount one on a post approximately 1.5 meters high.
5. Each team should be given two thermometers. Prior to placing the thermometers in their shelters, the students must make sure that the thermometers read the same temperature while indoors. If they do not, then they should be calibrated following the instructions in the Atmosphere protocols. If a thermometer does not read within 0.5 °C of 0 °C while in an ice water bath, that thermometer should not be used. Thermometers should not be placed in the shelters until the students are ready to take their shelters outside.

Day Three/Day Four

1. Choose a day that is mostly sunny and, ideally, slightly breezy. You do not want an overcast, rainy, or snowy day.
2. Each team should record the starting temperature of their thermometers. (Again, these should be the same.)
3. The thermometers should be placed in the shelters in such a way that they do not touch the cardboard (or paper) surface (unless, of course, the group is exploring the effect of the thermometer touching the shelter wall). If ready-made cardboard boxes are used, the thermometer can be hung by a string from the top of the shelter.
4. Each team takes its two shelters (with thermometers in them) outside. The teams investigating the physical properties of the shelter (color, slits, material) should find an open area away from buildings, preferably an open field. Teams investigating the placement of the shelter will split into two subgroups. One group will place its shelter in an appropriate area (grassy area, away from buildings). The other group will place its shelter in a non-ideal location. That is, to investigate the effects of shelter placement:
   - One shelter in an ideal location, one next to the sunny side of a building
   - One shelter in an ideal location, one in the middle of a parking lot, or other paved or asphalt surface
   - One shelter at 1.5 meters above the surface, the unmounted shelter on the ground at the base of the post
   - One shelter placed with its door facing north, the other one nearby with its door facing south.
5. After placing their shelters, students should record the temperature from each thermometer after about five minutes. They should then wait another five minutes and record the temperatures again. Temperatures should continue to be recorded at approximately five minute intervals, until the temperatures in the shelters have stabilized and do not change over two successive readings. Note that this may not necessarily take the same time for both shelters. That is, it may take one thermometer longer to reach the maximum temperature than the other. Therefore, it is important to check both thermometers.
6. Once the temperature has stabilized in both shelters, the students can bring their shelters and their recorded temperatures back to the classroom.
7. Each team should give a brief report of what it found to the entire class and then discuss why the temperatures may have behaved the way they did.
8. Each team should write a brief report showing its recorded temperatures. The team should discuss its findings in terms of how and why the particular parameter investigated affects the temperature.

Adaptations for Younger and Older Students

For younger students: The number of variables explored could be reduced to color, slits, placement near and away from buildings, and placement on natural and on concrete surfaces. Shelters could be placed on the ground instead of mounted on posts. (As long as they are all placed on the ground in the various areas, that factor will be consistent for all readings.)

For older students: Older students can explore which of the parameters is most important by making more than two shelters in each category. For example, they could test whether color is more important than slits by making one black and one white shelter without slits and one black and one white shelter with slits. See how many combinations they can come up with and which parameter has the greatest affect on the measured temperature. They can also explore what effect there is with the different shelter designs on a clear day versus a cloudy day, or a very calm day versus a windy day.

Student Assessment

Students' understanding of the importance of the shelter design and placement can be assessed in terms of:

- The conclusions they draw in their oral and written reports
- The understanding they show during the class discussions
- Their ability to deal with such additional questions as: What would be the effect if the white shelter became covered with a heavy layer of dust?
- The validity of the measurements they take.

Building a Thermometer

Purpose

To help students understand why and how a standard thermometer works

Overview

Students will construct a soda-bottle thermometer, which is similar to the thermometer used by GLOBE schools. Both are based on the principle that most substances expand and contract as their temperature changes. This experiment also demonstrates the principle of heat transfer.

Time

Two class periods

1. To do experiment - one class period
2. To discuss principles of expansion, contraction, and heat transfer through conduction and convection – 15 to 30 minutes
3. To record class data onto board or overhead and make graphs – 30 minutes
4. To have each group present to the class their results, ideas for other variables to test, and any problems that they encountered – 30 minutes

Level

Intermediate

Key Concepts

Substances expand and contract as the temperature changes.

Liquid-in-glass thermometers work on the basis of thermal expansion and contraction.

Conduction and convection are two forms of heat transfer.

Skills

Constructing an apparatus for an experiment

Conducting an experiment

Observing and *measuring*

Collecting, organizing and *recording* data

Working effectively in a group

Materials and Tools

(per group of students)

Ice

Water

One liter plastic soda bottle

Clear or white plastic drinking straw

Modeling clay. A one-pound block of modeling clay should be enough for 25 to 30 thermometers

Two 2-liter plastic soda bottles – the tops of these bottles need to be cut off

Scissors or knife to cut the top off the 2-liter plastic bottles

Food coloring (yellow does not work as well as red, blue, and green)

A watch or clock with a second hand

A metric ruler

A marker, grease pencil, or pen to mark the side of the straw

Building a Thermometer Activity Sheet

Preparation

Assemble materials.

Review principles of heat transfer.

Prerequisites

None

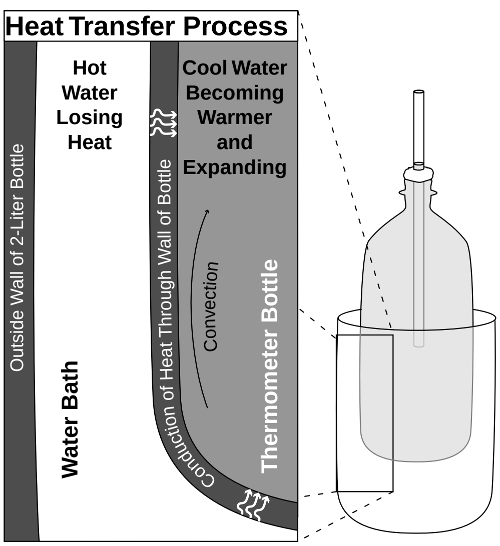
Background

For more information regarding how thermometers work, review *A Field View of the Atmosphere Investigation* in the *Welcome* section.

There are differences between the soda-bottle thermometer and the thermometer you use in GLOBE: the liquids used are different, the soda-bottle thermometer is not a closed system, and it lacks a numerical scale.

Several scientific principles are at work in this activity. One is the principle of expansion and contraction. Most substances expand when heated and contract when cooled. Over the range of temperatures in this experiment, water too expands when heated and contracts when cooled. (As water approaches its freezing point, it again expands.)

Figure ATM-L-4



Substances expand when heated because their kinetic energy, or energy of movement, increases with temperature. The molecules move faster and spread farther apart, causing the material to expand. When the substance is cooled, molecular movement decreases and the substance contracts.

In the case of water, the coefficient of expansion is quite small, so the volume of the water increases by only a very small percentage. Nonetheless, because all of the increase in volume is channeled into the small-diameter straw, the expansion can be seen.

This experiment also illustrates heat transfer by conduction. Conduction occurs when energy is transferred from one molecule to the next by direct contact, such as when the metal handle of a pan becomes hot. Metals are good conductors of heat. Wood is a poor conductor. In this experiment, the warm water in the outer container transfers its heat by conduction through the plastic wall of the one-liter bottle to the water in the inner bottle.

Although heat transfer by conduction can take place in solids, liquids, and gases, it is most efficient in solids and liquids. In the atmosphere, the air molecules in contact with the ground are heated by conduction. As these air molecules gain energy, they become less dense and start to rise.

Convection is the large-scale movement of a liquid or a gas which acts to redistribute heat throughout an entire volume. A common example of convection is water boiling in a pot. In this case, the water in contact with the bottom of the pot (where the heat source is) becomes heated and less dense than the water on top of it. This hot water rises, cooler water sinks and is then heated by contact with the bottom of the pot.

Preparation

This activity works well in teams of two or three students. Here are some job assignments and descriptions:

Student 1 Assembler - gathers materials and assembles the thermometer

Student 2 Timer/reporter – keeps track of 2-minute intervals when the experiment starts – makes marks on the straw showing how much the water has moved – measures the straw at the end of the experiment and tells the recorder the measurements – reports to the class the results of the experiment

Student 3 Recorder – records the measurements that the timer has made – also transfers the group's measurements onto the data sheets.

Make a copy of the Building a Thermometer Activity Sheet for each group of students.

The teacher should assemble materials before the class starts. If small groups are to be used, they should be assigned in advance. Students should bring in the 1-liter and 2-liter soda bottles. Allow a week or so to collect the necessary materials if students are supplying the bottles. Be sure to review the possible problems below before doing the experiment in class.

Be sure to understand the principles of heat transfer (conduction and convection) and the expansion and contraction of materials. Some examples of each in different situations would be helpful for a discussion. You may need to review how to measure in millimeters with the students.

Team Data Sheet *measurements in millimeters*

2 minutes	
4 minutes	
6 minutes	
8 minutes	
10 minutes	

Class Data Sheet

	Group A	B	C	D	Average
2 minutes					
4 minutes					
6 minutes					
8 minutes					
10 minutes					

What To Do and How To Do It

This activity can be done as a demonstration but is probably more effective if students or groups of students make their own thermometers. These instructions also appear on the *Building a Thermometer* Activity Sheet in the *Appendix* which can be copied and distributed to students.

Building the Thermometer

1. Fill the 1-liter soda bottle to the very top of the lip with cold tap water.
2. Add four drops of food coloring. This makes the water line easier to see. Blue, green, or red work best.
3. Roll some modeling clay into a small ball about 25 mm in diameter. Then roll it out so that it forms a cylinder about the length and diameter of a pencil. Flatten the pencil-shaped clay into a thick ribbon. Wrap the ribbon around the mid-point of the straw. See Figure ATM-L-5.

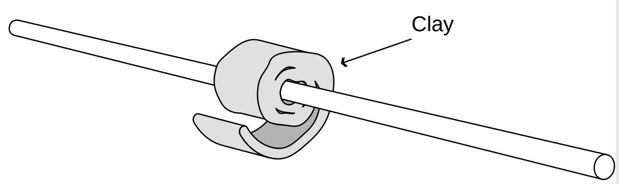


Figure ATM-L-5

4. Place the straw into the bottle and use the clay to seal off the bottle. Be careful not to pinch the straw closed. You also do not want any holes or cracks in the clay that would allow water to escape. One half of the straw will be inside the bottle and one half will be outside the bottle. Press the clay plug into the neck of the bottle far enough to force the water level up into the straw so that it can be seen. See Figure ATM-L-6.

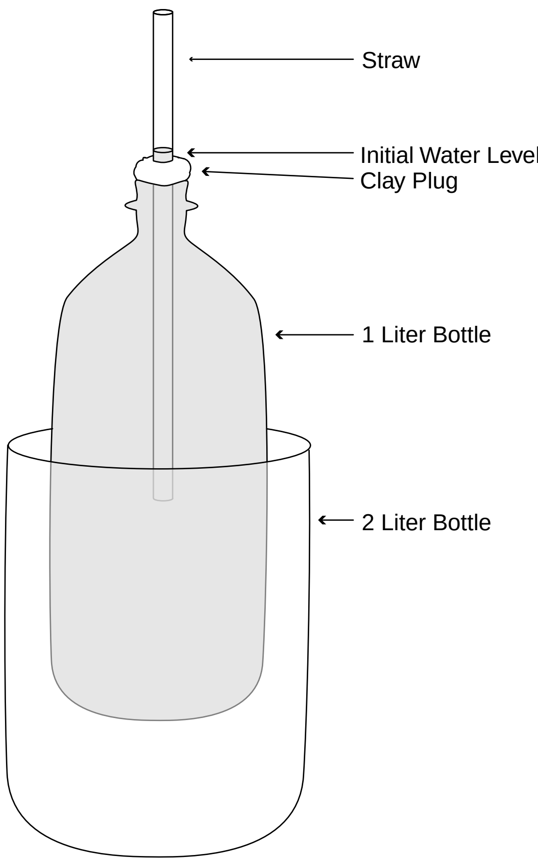
Experiment

1. Place the filled one-liter bottle (soda-bottle thermometer) into one two-liter plastic bottle container. Place a mark on the straw where you see the water line.
2. Fill the 2-liter container with hot tap water. Wait two minutes. Mark the straw at the water line. Repeat this marking

every two minutes, for ten minutes. At the end of the ten minutes, use a ruler to measure the distance of each mark from the original water mark at the bottom of the straw. Record your measurements on the team data sheet.

Watch closely for any changes. Do you see any? Describe what you observe.

3. Put ice and cold water into the second two-liter container.
4. Place the thermometer bottle into the ice water. Record your observations.



5. What happens to the water level in the straw when the thermometer is placed in hot water? (Answer: It rises about 4 cm if there's a 25 degree C difference.) Why? What happens to the water level when the thermometer is placed in cold water? (Answer: It falls.) Why?
6. Explain why you think this is happening.
7. Using your answer to question 6, how does the maximum-minimum thermometer, used for the noon temperature measurements for GLOBE, work?
8. What are two other things (variables) that, if changed, might cause this experiment to work differently? (A few answers: the amount of water touching the soda-bottle thermometer, the temperature of the water, the size of the container, the diameter of the straw.)
9. Graph the measurements that you recorded on your team data sheet. The x-axis (horizontal) should be the time (in minutes) and the y-axis (vertical) should be your measurements from the original line before the hot water is added (in millimeters). Be sure to give your graph a title and to label the axes of the graph so that someone else could understand it.
10. Make a class data sheet on a chalkboard or on a sheet of poster paper. Record your data on the Class Data Sheet. Combine your data with that of your classmates to find the average movement of water for each two-minute time period.
11. Add the average figures for the movement of water to your graph. Be sure to label this new line. How is the graph of your measurements different from the graph of the class average?
12. Explain the graph. What story does your graph tell? Can you draw any conclusions?
13. Why might it be important to have more than one trial when you are drawing conclusions?

Possible Problems with the Experiment

- The seal with the modeling clay has cracks in it, allowing the water to escape
- If the 1-liter water bottle is not filled to the top, it takes a longer time for the water to move up the straw. Indeed, the water may not move up the straw at all.
- There is not enough of a temperature difference between the water in the 1-liter bottle and the water in the 2-liter bottle. A 25 degree Celsius or larger difference is optimum. If there is a smaller difference, you will not get very large movements on

the straw. Hot tap water and cold tap water should have enough of a difference for the experiment to work.

- Students will forget to mark the beginning level in the straw. Be sure that they understand that the mark should be made immediately after placing the 1-liter bottle into the 2-liter bottle, before adding the hot water.
- If you have trouble getting or keeping ice in the classroom, you can omit this part of the experiment or show it as a demonstration.

Adaptations for Younger and Older Students

For younger students: Younger students can make the thermometer apparatus and observe the movement of the water in the straw, but not mark the water level at two-minute intervals. The teacher should cut the two-liter plastic container ahead of time.

For older students: Other variables could be tested, such as different size straws, larger or smaller containers for the hot water, or different size containers for the thermometers. The students could design their own experiment, conduct it, and present their findings to the class. They could calibrate their thermometer with a standard thermometer.

Further Investigations

1. Use a standard thermometer to measure the temperature of the water in the inside of the soda-bottle thermometer and compare it to the temperature of the water outside the thermometer. Does the amount of water movement in the straw change when there are different temperatures? Perform an experiment, keep records, and present your findings to the class.
2. Does the size of the containers affect the way the thermometer works? Design an experiment that tests this concept, do the experiment, and make a chart showing your results.
3. Go to the library and research what materials are used to make different thermometers. Be sure to find out the different principles on which they operate. Present your findings to the class.
4. Call the local weather offices or television or radio stations and see what type of thermometers are used there. Take a trip to visit the weather station. Take pictures and make a poster to share with your class.
5. Make thermometers using different diameters of straws and see if there are any differences. What do you think might have caused any differences you see? Would this have an effect on the construction of real thermometers?
6. Find out how scientists record the temperature at different depths of the ocean. On a map of the oceans, show the average water temperature. Make a chart to share with the class.

Student Assessment

Students should be able to answer the questions in the experiment on the student activity sheet. They should also be able to explain how a thermometer works in class or on a quiz.

Building a Thermometer Activity Sheet

Duplicate and distribute to students.

Purpose

To help you understand how and why a liquid-in-glass thermometer works.

Overview

The soft drink bottle thermometer that you construct in this activity is similar to the thermometer you use in the GLOBE Instrument Shelter. However, there are differences. Both use liquids, but the liquids are different. Do you know what liquid is in the standard GLOBE thermometer? Also, the thermometer you will make has no degree markings. But the principles of operation are the same for both types of thermometers.

The thermometer you use for measurements and the instruments you will build are both based on the principle that substances expand and contract as their temperature changes.

This lab also demonstrates the principle of heat transfer. When a warm object is placed against a cold object heat is transferred from the warm object to the cold object by conduction. For example, in the winter if you place your bare hand on the fender of an automobile, your hand transfers heat to the metal by conduction.

Usually when you work in a job, you are part of a team. In this activity you will also be part of a team. Here are your job descriptions:

Student 1 – assembler - gathers materials and assembles the thermometer

Student 2 – timer/reporter - uses clock or watch to keep track of 2-minute intervals when the experiment starts - makes marks on the straw showing how much the water has moved - measures the straw at the end of the experiment and tells recorder the measurements - reports to the class the results of the experiment

Student 3 – recorder - records the measurements that the timer has made - also transfers the group's measurements onto the class chart

Materials and Tools

(per group of students)

Ice

Water

One liter plastic soda bottle

Clear or white plastic drinking straw

Modeling clay (a ball about 25 mm in diameter)

Scissors or knife to cut the top off the two liter plastic bottle

2 two-liter plastic soda bottles - the top of the bottle needs to be cut off so that it is used as a container to hold water and the 1 liter plastic soda bottle

Food coloring (yellow doesn't work as well as red, blue, and green)

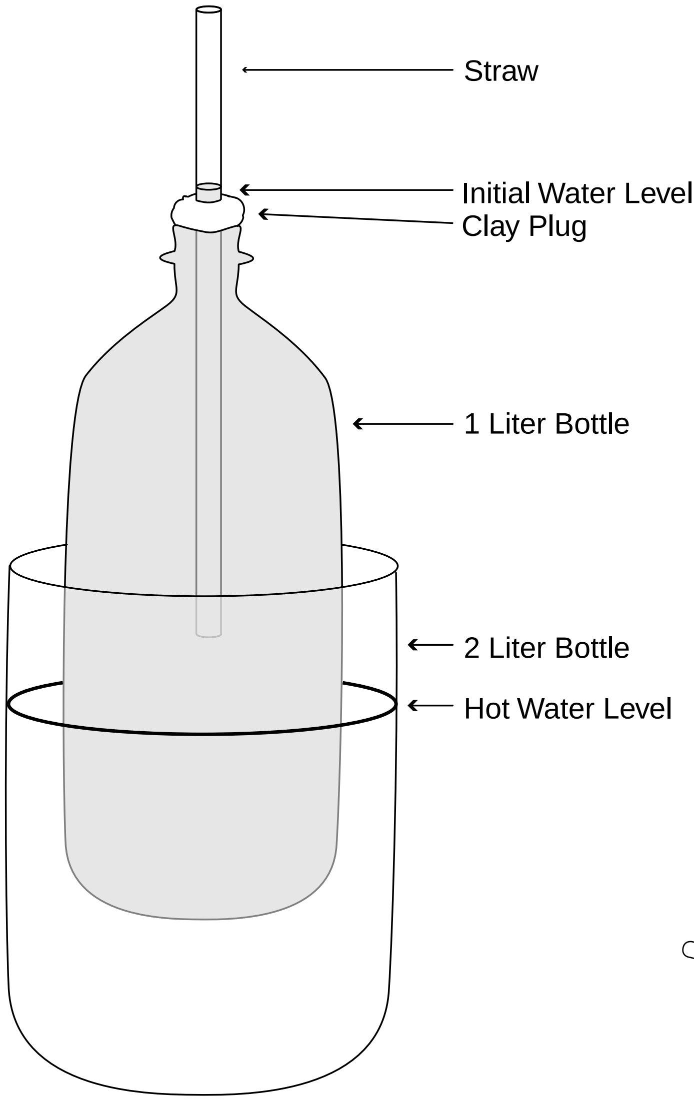
Watch or clock with second hand

Metric ruler

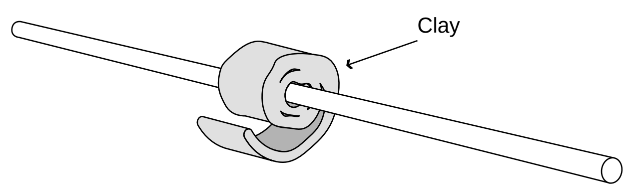
Marker, grease pencil, or pen to make marks on the side of the straw

Building the Thermometer

1. Fill the one liter soft drink bottle to the very top of the lip with cold tap water.
2. Add four drops of food coloring – this helps make the water line easier to see. Blue, green, or red work best.



3. Roll some modeling clay into a small ball about 25 mm in diameter. Then roll it out so that it forms a cylinder about the length and diameter of a pencil. Flatten the pencil-shaped clay into a thick ribbon. Wrap the ribbon around the midpoint of the straw.
4. Place the straw into the bottle and use the clay to seal off the bottle. In doing this, be careful not to pinch the straw closed. You also do not want any holes or cracks in the clay that would allow water to escape. One half of the straw will be inside the bottle and one half will be outside the bottle. Press the clay plug into the neck of the bottle far enough to force the water level up into the straw so that it can be seen.



Experiment

1. Place the filled one liter bottle (the soft drink bottle thermometer) into the empty two liter plastic bottle container. Place a mark on the straw where you see the water line.
2. Fill the two liter container with hot tap water. Wait two minutes. Mark the straw at the water line. Repeat this marking every two minutes, for ten minutes. At the end of ten minutes use a ruler to measure the distance of each mark from the original water mark at the bottom of the straw. Record your measurements on the team data sheet, below.

Duplicate and distribute to students.

Team Data Sheet

Time	*Measurements in millimeters*
2 minutes	
4 minutes	
6 minutes	
8 minutes	
10 minutes	

Watch closely for any changes. Do you see any? Describe what you observe.

____

____

3. Put ice and cold water into the second two-liter container.

4. Place the thermometer bottle into the ice water. Record your observations.

____

____

____

____

5. What happens to the water level in the straw when the thermometer is placed in hot water?

____

____

____

What happens to the water level in the straw when the thermometer is placed in cold water?

____

____

____

Duplicate and distribute to students.

6. Explain why you think these changes happen.

7. Using your answers to question 6, how does the maximum-minimum thermometer used for the GLOBE measurements work?

8. What are two other things (variables) that, if changed, might cause this experiment to work differently?

9. Graph the measurements that you recorded in your team data sheet at step number 2. The x-axis (horizontal) should be the time (in minutes) and the y-axis (vertical) should be your measurements (in millimeters) from the original line before the hot water was added. Be sure to give your graph a title and to label the axes of the graph so that someone else could understand it.

10. Record your data on the Class Data Sheet on the board or as your teacher instructs. Combine your data with that of your classmates to find the average movement of water for each two-minute time period.

11. Add the average figures for the movement of water to your own graph. Be sure to label this new line. How is the graph of your measurements different from the graph of the class average?

12. Explain the graph. What story does your graph tell? Can you draw any conclusions?

13. Why might it be important to have more than one trial when you are drawing conclusions?

Land, Water, and Air

Purpose
To help students understand that land and water heat and cool at different rates and that the properties of soil and water influence the heating of air above them

Overview
Students measure temperature changes in soil, water, and air as they are exposed to the heating action of the sun.

Time
Three to four hours total
one to two hours of actual time on task

Level
Intermediate and advanced

Key Concepts
Different substances, such as soil, water, and air, transfer energy and heat at different rates

Skills
Designing and *conducting* an experiment
Measuring and *recording* data
Organizing data in tables
Graphing
Working effectively in groups

Materials and Tools
(per group of students)

Two plastic buckets at least 30 cm tall
A centimeter ruler
Six thermometers
A means to suspend the thermometers over the buckets, such as string and dowels

Preparation
Arrange for an outdoor area in which to conduct the experiment. (This activity could be performed indoors by substituting a strong artificial light source for the sunlight.) This experiment gives the best results on a sunny, warm day. Divide the students into small working groups. You may want to demonstrate the activity first so that all students understand how to conduct the experiment.

Prerequisites
None

Background
One of the important reasons why we have different kinds of weather throughout the world is because land and water heat and cool at different rates.

For example, afternoon thunderstorms in Florida are often initiated by the fact that during the day the land heats up faster than the water does. (To understand more about this, students should research what causes sea breezes.) In parts of the world that experience monsoons (wind systems that reverse direction seasonally), the rainy part of the monsoon season is characterized by alternating periods of active (rainy) and non-active (not-rainy) weather depending on whether the land is dry or wet.

Students may have observed a difference in the heating and cooling rates of land relative to water if they have ever run barefoot across a beach to the water in the middle of a warm, sunny afternoon. They probably remember how hot the land was and how cool and refreshing the water was. If they were at the beach until after sunset and walked barefoot across the beach to the water, they might remember that at this time of day, it is the beach that feels cool, while the water feels warm. Students can study this land/water difference with a simple experiment.

What To Do and How To Do It

Fill one bucket with soil to a depth of approximately 15 centimeters. Fill the other bucket to the same depth with cool water (as from an outdoor faucet). Set both buckets out in the sun. In each bucket suspend a thermometer one cm above, one cm below, and eight cm below the surface. Try to position the thermometers so that the sunlight is not shining directly on the bulb or the glass tube. Allow time for the thermometer temperatures to stabilize. Record the initial thermometer readings.

Read the temperature of each thermometer at two minute intervals for 20 minutes. Then read the temperatures at one, two, and three hours.

Questions for Discussion

Is the temperature of the soil one cm below the surface warmer than it was when students set out the buckets three hours ago? Is the surface temperature of the water warmer now than it was three hours ago? Why?

Which temperature reading is higher at a depth of 8 cm, that of the soil or that of the water? What conclusions can students draw from this experiment?

What your students should have found was that the soil's surface was much warmer at one cm than that of the water at one cm. On the other hand, the water was warmer at a depth of 8 cm after 3 hours than the soil at a depth of 8 cm. The temperatures at one cm above the surface should be higher for the soil than for the water.

Liquid water molecules move much more freely than the molecules that make up soil. Therefore, water can distribute heat throughout a greater volume than can soil. That is why, after three hours in the sun, the water in the bucket was warmer at the 8 cm depth than was the soil. After sunset, the heat absorbed by soil quickly escapes to the atmosphere, and the land cools rapidly. However, although water heats up more slowly than land, once it is heated it takes longer to cool. If students were to repeat the measurements several hours after sunset, they would find that the water temperature at one cm depth was higher than that of the soil at one cm depth.

Cloud Watch

Purpose
To track clouds and weather, and begin to understand the connection between the two

Overview
Students observe clouds over a five-day period and correlate these observations with the weather.

Time
Ten minutes per day for five days; plus perhaps half of one class period to discuss

Level
All

Key Concepts
Relationship of clouds and changes in clouds to weather

Skills
Systematically *observing* over a period of time

Correlating one observed phenomenon with another

Materials and Tools
GLOBE Science Notebooks and cloud charts

Preparation
Divide the students into small working groups. Discuss how they will record their observations in their GLOBE Science Notebooks.

Prerequisites
None

What To Do And How To Do It

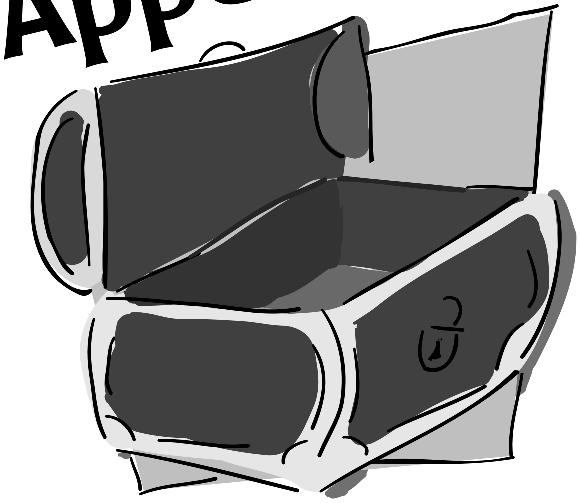
Over a five-day period, students should carefully look at the clouds and write down what they see. If they do not yet know the names of the clouds, they can write down what the clouds look like. It is best if they can check the sky three times per day: once in the morning (on the way to school); once in the early afternoon (around lunchtime); and once in the late afternoon or evening (perhaps on the way home from school). The exact times of each observation are not critical, although it will help if the observations are made at roughly the same time each day. (For example, the morning observations should all be made around 8 am, rather than at 7 am one day, and 10 am the next day. The same is true for the noontime and evening observations).

At the end of each day, students should also record the weather for that day. Was it a rainy morning and clear afternoon? Did it snow all day? Was it calm and humid? The students do not need to quantify their weather reports (i.e., they don't have to write down "21 millimeters of rain" or "79% relative humidity"), but should describe the weather as completely and clearly as possible.

As the students record their cloud and weather observations, they should look for any patterns. For example, are cirrus clouds (thin, wispy clouds) in the morning typically followed by afternoon thunderstorms? Are the small puffy clouds (cumulus) ever associated with precipitation?

After a week of recording clouds and weather, ask students to use their observations to predict what the weather will be like tomorrow. Ask them to explain why they made their predictions. Have each student keep track of how well they do in forecasting the weather. They may develop a new respect for the difficulty of forecasting!

Appendix



Data Work Sheet

Observing Cloud Type

Glossary

GLOBE Web Data Entry Sheets

Atmosphere Investigation
Data Work Sheet

School Name ______________________________________

Observer Names ___________________________________

Measurement method for pH: ❒ paper ❒ pen ❒ meter

	Sat.	Sun.	Mon.	Tues.	Wed.	Thur.	Fri.
Date							
Hour (Universal Time)							
Observer Names							

Cloud type (Check all types seen)

Cirrus	❒	❒	❒	❒	❒	❒	❒
Cirrocumulus	❒	❒	❒	❒	❒	❒	❒
Cirrostratus	❒	❒	❒	❒	❒	❒	❒
Altostratus	❒	❒	❒	❒	❒	❒	❒
Altocumulus	❒	❒	❒	❒	❒	❒	❒
Stratus	❒	❒	❒	❒	❒	❒	❒
Stratocumulus	❒	❒	❒	❒	❒	❒	❒
Nimbostratus	❒	❒	❒	❒	❒	❒	❒
Cumulus	❒	❒	❒	❒	❒	❒	❒
Cumulonimbus	❒	❒	❒	❒	❒	❒	❒

Cloud Cover (Check one)

Clear	❒	❒	❒	❒	❒	❒	❒
Scattered	❒	❒	❒	❒	❒	❒	❒
Broken	❒	❒	❒	❒	❒	❒	❒
Overcast	❒	❒	❒	❒	❒	❒	❒

Rainfall

Number of days rain has accumulated							
Rainwater in rain gauge (mm)*							

** Remember:*
Record 0.0 when there has been no rainfall or snowfall.
Record M if the measurement is lost or missing for this day.
Record T for trace amount of rainfall (less than 0.5 mm) or snowfall (too small to measure).

Atmosphere Investigation Data Work Sheet (Continued)

	Sat.	Sun.	Mon.	Tues.	Wed.	Thur.	Fri.
Date							
Hour (Universal Time)							
Observer Names							

Snowfall

Total depth of snow on the ground: (mm)							
Number of days snow has accumulated on the snowboard: (mm)							
Depth of new snow on the snowboard: (mm)*							
Daily liquid equivalent of the new snow: (mm)							

Precipitation pH

pH of the rain or melted snow:							

Maximum, Minimum, and Current Temperatures

Current air temperature: (in deg rees C)							
Maximum daily air temperature: (in deg rees C)							
Minimum daily air temperature: (in deg rees C)							

Notes: (Unusual conditions.)

** Remember:*
Record 0.0 when there has been no rainfall or snowfall.
Record M if the measurement is lost or missing for this day.
Record T for trace amount of rainfall (less than 0.5 mm) or snowfall (too small to measure).

Observing Cloud Type

There are five descriptive terms for the various types of clouds:

CIRRO or high clouds
ALTO or middle clouds
CUMULUS or white puffy clouds
STRATUS or layered clouds
NIMBUS or clouds from which precipitation is falling

The following ten types of clouds, named using the above terms, are to be used when reporting the cloud type for your area:

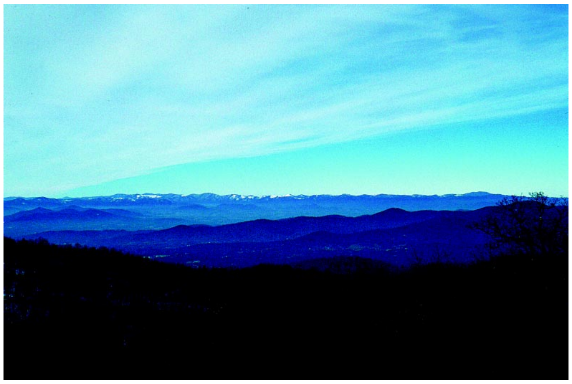
High Clouds

Cirrus

These clouds look like white delicate feathers. They are generally white wispy forms. They contain ice crystals.

Cirrocumulus

These clouds are thin white layers with a texture giving them the look of patches of cotton or ripples without shadows. They contain primarily ice crystals and perhaps some very cold water droplets.



Cirrostratus

These clouds are a thin, almost transparent, whitish layer made up of ice crystals. They may totally or partly cover the sky and can create a halo appearance around the sun.

Middle Clouds

Altostratus

These clouds form a bluish or grayish veil that totally or partially covers the sky. The light of the sun can be seen through them but there is no halo effect.

Altocumulus

These clouds look like waves of the sea with white and gray coloring and shadows. They contain mostly water droplets and perhaps some ice crystals.

Low Clouds

Stratus

These clouds are gray and lie very close to the surface of the Earth. They usually look like a sheet layer but sometimes are found in patches. They rarely produce precipitation.

Stratocumulus

These clouds are a gray or whitish color. The bases of these clouds tend to be more round than flat. They can be formed from old stratus clouds or from cumulus clouds that are spreading out. Their tops also tend to be mostly flat.

Nimbostratus

This is a very dark and gray-colored cloud layer that blots out the light of the sun. It is massive and has a continuous fall of precipitation.

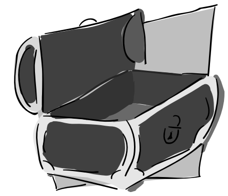
Cumulus

These clouds have a flat base and a dense, mound-shaped top that resembles a large cauliflower. Where the sun hits these clouds they are a brilliant white. The base tends to be a darker gray. They generally do not produce precipitation.

Cumulonimbus

These are large, heavy, and dense clouds. They have a generally flat, dark surface with very tall and large tops like the shape of a massive mountain or anvil. These clouds are often associated with lightning, thunder and sometimes hail. They may also produce tornados.

Glossary



acidic precipitation
Rain or snow with a pH lower than 5.6, which is the naturally occurring value for rain or snow in equilibrium with the carbon dioxide in the air.

aerosols
Liquid or solid particles dispersed or suspended in the air. This term is not used for rain or cloud droplets nor for ice crystals.

air temperature
A measure of the degree of hotness or coldness of the air.

cloud
A visible form of condensed water in the atmosphere. This may include water droplets and ice crystals. In addition, clouds may include aerosols or solid particles such as those present in fumes, smoke or dust.

cloud cover
Refers to the amount (in tenths) of the sky which is covered by clouds.

current temperature
The temperature at the time the thermometer is read.

high clouds
These clouds, found above 6,000 m, are made up of mostly ice crystals.

liquid precipitation
Includes rainfall and drizzle.

local solar noon
Solar noon is used in this Teachers' Guide as the time when the sun appears to have reached its highest point in the sky during the day. It occurs halfway between sunrise and sunset.

low clouds
Low clouds, found below 2,000 m, mostly contain water but also can be made up of snow and ice particles.

maximum temperature
The highest temperature that has occurred since the preceding temperature reading and resetting of the thermometer.

meniscus
The curved surface of a liquid confined in a narrow tube due to the adhesion of the liquid to the interior surface of the tube.

middle clouds
These clouds are made up of mostly liquid water. The base of these clouds can range in height from 2,000 m to 6,000 m.

minimum temperature
The lowest temperature that has occurred since the preceding temperature reading and resetting of the thermometer.

precipitation
Refers to any or all forms of liquid or solid water particles that fall from the atmosphere and reach Earth's surface.

solid precipitation
Includes snow, ice pellets, hail, ice crystals, and, for the purpose of precipitation measurements, freezing rain.

water equivalent
The liquid content of a sample of solid precipitation. This is determined by melting the sample and measuring the resulting amount of water.

Atmosphere Investigation

Atmosphere Study Site Data Entry Sheet

School Name

Measurement Time:
Year: **Month:** Select **Day:** **Hour:** **UT**
Current Time: 1997 June 18, 20 UT

Name of site:
Create a unique name that describes the location of your site.

Please supply as much of the following information as you can now. When you obtain additional information click on the Entry button and go to "Edit a Study Site".

Source of data: ○ **GPS** ○ **Other**

Latitude: deg min ○ **North** ○ **South** of the Equator
(Enter the data in the format 56 deg 12.84 min **and** mark whether it is North or South.)

Longitude: deg min ○ **East** ○ **West** of the Prime Meridian
(Enter the data in the format 102 deg 43.90 min **and** mark whether it is East or West.)

Elevation: meters

Distance of Site to Nearest Building or Tree: meters

Height of Nearest Building or Tree : meters

Surface Cover of Site: ○ paved ○ bare ground ○ short grass (< 10 cm) ○ long grass (> 10 cm)

Enter the most detailed MUC level MUC Code :

Enter MUC Name :

Send Erase

NOAA/Forecast Systems Laboratory, Boulder,Colorado

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: 1997 June 19, 16 UT

Study Site Location: [02OUTSIDE]

Only enter data that was measured at the same measurement time and Study Site Location.

Cloud Observations:

Cloud Cover:

○ Clear ○ Scattered ○ Broken ○ Overcast

Cloud Type(s):

High : ☐ Cirrus ☐ Cirrocumulus ☐ Cirrostratus
Middle: ☐ Altostratus ☐ Altocumulus
Low : ☐ Cumulus ☐ Nimbostratus ☐ Stratus ☐ Stratocumulus ☐ Cumulonimbus

Comments: [ ]

Air Temperature:

Current Air Temperature: [ ] degrees Celsius
Maximum Daily Air Temperature: [ ] degrees Celsius
Minimum Daily Air Temperature: [ ] degrees Celsius
Comments: [ ]

Precipitation:

Enter either Liquid or Solid Precipitation.
Enter **T** for a trace amount or **M** for missing data.

LIQUID PRECIPITATION:
Rain Amount : [ ] mm **over** [1] day(s)
pH of Rain: [ ] **measured with** [Select]
Comments: [ ]

SOLID PRECIPITATION:
Total Snow Accumulation: [ ] mm
Daily Snow Accumulation: [ ] mm **over** [1] day(s)
Liquid Equivalent : [ ] mm
pH of Snow: [ ] **measured with** [Select]
Comments: [ ]

[Send] [Erase]

NOAA/Forecast Systems Laboratory, Boulder,Colorado

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: 1997 June 18, 20 UT

Study Site Location: [02OUTSIDE]

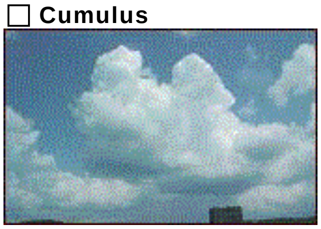
CLOUD COVER:

○ Clear ○ Scattered ○ Broken ○ Overcast

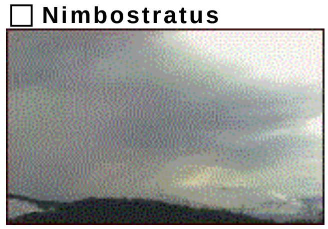
CLOUD TYPE:

Low Clouds:

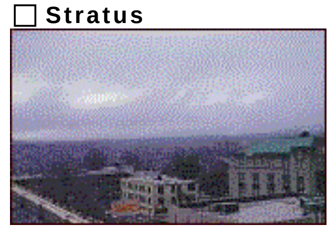
☐ **Cumulus**



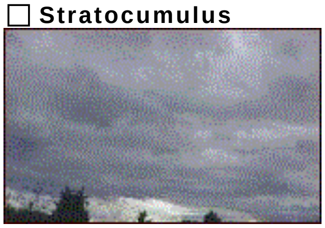
☐ **Nimbostratus**



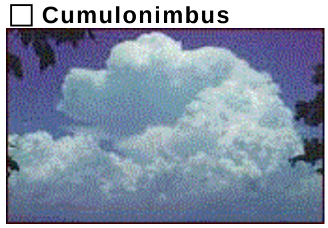
☐ **Stratus**



☐ **Stratocumulus**

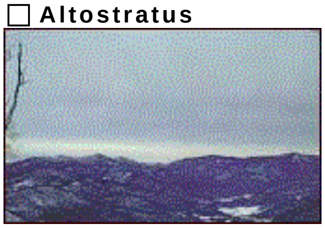


☐ **Cumulonimbus**

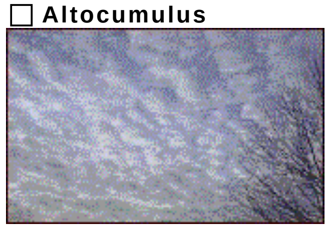


Middle Clouds:

☐ **Altostratus**



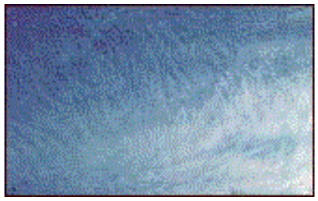
☐ **Altocumulus**



High Clouds:

Cirrus

Cirrocumulus



Cirrostratus

Comments:

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